THE PRODUCTION OF SILAGE IN SMALL CONTAINERS FOR SMALL SCALE FARMERS

BY

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DECLARATION

I Letsoalo Mokgatsana Lerato Victoria declare that the work submitted as partial fulfillment to the University of Limpopo for the degree Master of Science (Pasture Science) are results from my own investigation and it is not partially presented or investigated by anyone in any universities anywhere. The work used when citing as a source of information have punctually been acknowledged by reference to the authors.

Student’s signature   Date

ACKNOWLEDGEMENT

I will like to express my gratitude to Almighty God for his blessing on me, the strength and courage to carryout my studies for without Him nothing possible. Isaiah 55:11 “So is my word that goes out of my mouth, it will not return to me empty, but will accomplish what I desire and achieve the purpose for which I sent it”.

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ABSTRACT

The Limpopo Province is a well known for its warm summers and dry winters. The lack of rainfall in winter causes a shortage of feed for livestock and is responsible for poor animal production and even mortality. Alternatives winter feeding strategies that have been suggested by researchers are planted pastures, crop residues, hay, foggage and silage. Silage in “small container” is the cheapest potential alternative fodder source. This preliminary study investigated the use of small container silage during winter on small scale farms by using *Panicum maximum*, maize, pearl millet and forage sorghum.

Dewageningsdrift (Hygrotech Experimental Farm, Gauteng) was used for this research project. The treatments were four crops (Maize, forage sorghum, pearl millet and *Panicum maximum*) ensiled in three ensiling techniques (small plastic bags, black plastic bags and buckets). During the first season (2009/2010) the samples were collected in a maturity stage. During second season (2010/2011) the samples were collected in different growing stages (soft dough, hard dough and matured stage).

If all quality norms are taken into consideration maize can still be classified as a good silage crop. Silage of similar quality can be produced from forage sorghum and pearl millet. Pearl millet produced relative good quality silage when ensiled in a mature stage.

Ensiling in small plastic bags and buckets resulted in good quality silage. There was a trend that buckets resulted in better quality silage when harvested in the hard dough stage. Black refuge plastic bags are not suggested for silage making.

Although the quality is lower, silage can be produced from hard dough and mature material, especially with pearl millet in buckets.

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LIST OF ABBREVIATION

LDA	Limpopo department of agriculture
DM	Dry matter
SAS	Statistical analysis software
WSC	Water soluble carbohydrates
LBS	Little bag silage
NH_3	Ammonia
LA	Lactic acid
ADF	Acid detergent fibre
NDF	Neutral detergent fibre
CP	Crude protein
Max	Maximum
Rel Hum	Relative humidity
Temp	Temperature
Min	Minimum
R	Rainfall
ºC	Degree celcius
%	Percentage
m/s	Meter per second
mm	Millmeter
RCBD	Randomized Complete Blocked Design
spp	Species
ℓ	Liter
LSD	Least significant difference
ANOVA	Indicates Analysis Of Variances
KZN	Kwa Zulu Natal
REP	Replication
H_2O	Water

CHAPTER 1

GENERAL INTRODUCTION

1.1 BACKGROUND

1.1.1 Constraints in animal production in the Limpopo Province

Reyneke (1971) and Lishman (1992) indicated that a shortage of adequate good quality herbage during the winter period is one of the biggest problems confronting the livestock farmer in the summer rainfall areas. In general the provision of fodder for the late winter and autumn remains a problem. Beside small quantities of crop residues, the livestock farmers in Limpopo Province depend on good managed winter veld or conserved roughage (hay or silage). Another form of roughage is foggage, which is a cultivated pasture is grazed or cut during the first part of the growing season and rested thereafter for utilization in winter (Dannhauser 1991).

The Limpopo Province is well known for its warm summers and dry winters. The lack of rainfall in winter is causing a shortage of feed for livestock and is responsible for poor animal production and even mortality of livestock (Dannhauser 1991). With the growth in population and signs of global climate change there is thus always a need for winter feed. Engelbrecht *et al*. (2004) also quoted that in regions where winters are cold and dry, silage can play a role as conserved roughage. The advantages of silage above hay is that it is less dependent on the weather, has no fire hazard and quality is maintained for a longer period.

1.1.2 Alternatives winter feeding strategies

Planted pasture

Planted pastures, produced on marginal soils, are valuable roughage, but the economical impact thereof on the livestock industry should be carefully considered. A recent review showed that beef production systems that were economically feasible two decades ago, are not necessarily economical feasible now, due to increased input costs, mainly in the form of fertilization and haymaking (Dannhauser[1] 2013. Pers. comm). One major reason for planting pastures is that some species grow and provide grazing during the period when natural pastures are dormant and unproductive. Nutritive quality is high and this reduces the need for feeding of protein and energy supplements. Pastures are expensive due to the seedbed preparation in addition to seed, fertilizer, etc (Tainton 2000).

Foggage

According to Bartholomew *et al*. (1998), foggage refer to herbage that has been allowed to grow out during autumn and which is conserved on the land to be grazed when required during winter. Foggage is used in dryer area in South Africa but it is mainly used for beef cattle and not good enough quality for dairy cattle for example (Tainton 2000).

Crop residues

Crop residues offer great potential as a relatively cheap feed source for the livestock industry and is sometimes regarded as crucial for livestock survival in winter (Crichton *et al*. 1998). However, farmers tend to withdraw the more marginal soils from cash cropping due to the following limiting factors (Van Zyl 2006):

- A price–cost squeeze in cash cropping.
- Climatic risk like short, severe droughts especially in Limpopo.
- Soil restrictions, like acidity build up and aluminum toxicity.

This has resulted in a reduction in the availability of crop residue for livestock. Minimum tillage cultivation practices on grain crop lands are gaining popularity. These practices inhibit the utilization of residues to a large extent, and contribute further to the decrease in residues available for livestock (Van Zyl 2006). In most parts of the crop production areas, maize residues make an extremely important contribution to the forage

[1] Personal communication: CS Dannhauser, School of Agriculture and Environmental Science. University of Limpopo, Private Bag X1160, Sovenga, 0727.

requirements of animals during winter, which is most difficult in Limpopo Province due to its unpredictable low rainfall (Tainton 2000).

1.1.3 Silage and silage making

Silage preserves wet forage material in a much better state than hay and foggage because it is protected against the damaging effects of the sun, insects, fire, and animals and mould while hay and foggage are not. Silage is fermented, high moisture fodder that can be fed to ruminants or used as a bio-fuel in for anaerobic digesters. It is fermented and stored in a process called ensilage and is usually made from grass crops and cereals, using the entire green plant. Lactic acid is produced when the sugars in the forage plants are fermented by bacteria in a sealed container under anaerobic conditions. Silage is very palatable to livestock and can be fed at any time.The fermentation during ensilaging is an anaerobic process. Silage plays an important role in feeding high productive animals, such as dairy cows in dry periods (Mhere 2002).

According to Machine (1999), the quality of the ensiled product depends on the feeding value of the material ensiled the fermentation products process and the chemistry thereof. The main role silage play is to build up feed conservation that will be utilized during periods of feed deficiency, e.g. dry season or winter, as a routine feed supplement to increase productivity of animals (McDonald *et al*. 1991).

According to Lane (2000), “Little bag silage” (LBS) has been developed in northern Pakistan and in Nepal as a workable system for small holder farmers. A key feature of LBS is that it allows conservation of available fodder in small quantities over a long period of time. Small quantities can be made in small plastic bags like those traditionally obtained at from local shops (Lane, 2000).

According to Ranji *et al*. (2002), the wet (higher moisture content) silage has more biological activity of different kinds. However if a silage is too dry, there will be no enough moisture to support sufficient microbial growth to produce the acids which reduce the pH and preserve the crop (Ranji *et al*. 2002). Silage that is too dry will not ferment enough to reduce pH to a level that will kill spoilage-causing yeasts, moulds and aerobic bacteria (see Figure. 1.1). In wet silage, the spaces between the plant materials are filled with water, but in dry silages they are filled with air. Also, dry material tends to be more springy and resistant to compaction. These consume valuable nutrients, produce heat and thus cause spoilage. Heating is a particular problem, because as the silage heats up, the yeasts and moulds proliferates faster (Ranji *et al*., 2002).

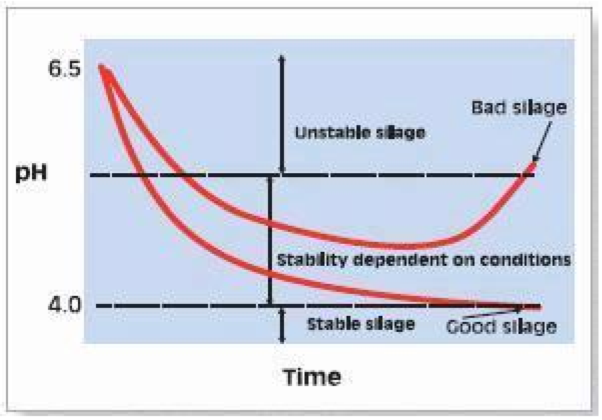

Figure 1.1 pH decline and silage stability.

1.2 Problem statement

Small scale framers sometimes fail to give a high animal production output due to a lack of feeding during the dry (winter) season. For small scale farmers with limited production capacity, finding enough feed in the winter months to maintain high production is always a problem. Many are forced to buy hay, concentrates or silage just to keep their animals alive and are unable to benefit due to the higher prices paid for animal feed in the winter months. So, the use of small container silage might be the solution to maximize animal production, at lower cost, to reduce the losses of production.

1.3 Motivation of the study

Many farmers have experienced high losses of animals due to shortage of feed during winter on small-scale farms, which results in lower animal production. It is of benefit to these small scale farmers to come up with ways of correcting this problem. To overcome this problem, farmers can use forage grown in the wet season and conserved as silage for winter. The use of small container silage on small scale farms might be a way to reduce shortages of feeds during dry season. For livestock production to be successful there must be a year round feed supply. If veld grazing only produces sufficient forage for four months of the year, it is important to produce and conserve forages in sufficient quantity and of good quality. Conserved forage is needed to maintain livestock production over the dry months (6 to 8 months).

1.4 Aim and objectives

1.4.1 Aim

The study was aimed to investigate the use of small container silage, during winter on small scale farms, by using pearl millet, maize, *Panicum maximum* (veld grass) and forage sorghum.

1.4.2 Objectives

Objective 1: To determine the effect of different ensiling techniques in different containers on the quality of silage.

Objective 2: To determine the quality of silage made from different species in small containers.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Provision of feed for livestock during dry periods and specifically during winter is one of the biggest challenges that farmers experience in the low rainfall areas of South Africa. The study was aimed to examine the effect of different ensiling techniques on the quality of silage to be used on small scale farms.

Approximately 65% of the country is arid or semi-arid, with only 28% of the country receiving more than 600 mm of rainfall per annum. In the past, several researcher have investigate alternative or supplementary feed sources for winter feeding [Meaker and (Lesch 1974), (Meaker 1978), Erasmus and Barnard (1985), Van Niekerk and Jacobs (1985), Van Niekerk *et al*. 1990, (Hardy 1991) and (Lyle 2003)]. The role of commercial scale of silage is also well researched in South Africa, however silage for small scale farmers are relatively unknown.

2.2 ALTERNATIVE WINTER FEEDING STRATEGIES

Discussions of some of the feeding strategies suggested by researches are as follows:

2.2.1 Planted pastures

Planted pastures on marginal soils, are valuable roughage, but the economic impact thereof on the livestock industry should be carefully considered. A recent review showed that beef production systems that were economically feasible two decades ago, are not necessarily so now, due to increased input costs, mainly in the form of fertilization and haymaking (Dannhauser 2013[2]. Pers. Comm.). Even in the high rainfall areas the use of irrigated pasture, like ryegrass (*Lolium multiflorum*), is declining due to increasing input costs (Van Zyl 2006).

[2] Personal communication: CS Dannhauser, School of Agriculture and Environmental Science. University of Limpopo, Private Bag X1160, Sovenga, 0727.

2.2.2 Crop residues

Crop residues offer great potential as a relatively cheap feed source for the livestock industry and is sometimes regarded as crucial for livestock survival in winter (Crichton *et al*. 1998), especially in the maize producing areas. Because of increasing input costs farmers withdraw the more marginal soils from cash cropping (Van Zyl 2006). Limpopo Province as a whole is a marginal area for crop production, because of low rainfall, and crops are not freely available to use. Almost any crop residue can be fed to livestock. However, the residues of maize, sugar cane, grain sorghum, soybean and wheat are seen as some of the best sources of animal feeding (Van Zyl 2006).

Problems experienced when feeding crop residues include (McDonald *et al*. 2002):

- Bloat, although uncommon.
- Acidosis.
- Many crops are prone to regrowth and the young shoots cause prussic acid poisoning. Sorghums are known for this problem when late rains and high temperatures stimulate plant growth.
- Brassicas (cabbage, cauliflower, Brussels sprouts) all produce substances that block the uptake of iodine and when animals graze these crops or the residues for a long, uninterrupted period, iodine deficiency symptoms occur (*e.g.* abortions and death of young animals).
- Some crops produce toxins, like solanine, which is present in the leaves of many plants, especially potatoes.
- Blockage of the esophagus in ruminants, which happens when animals do not succeed in swallowing partly solid pieces of food such as tubers of potatoes, carrots or radishes (Tainton 2000).

2.2.3 Hay

Van Zyl (2006) reported that the value of hay for wintering practices is an alternative to veld (feed in paddocks) and this topic was well researched by Meaker (1978), Meaker *et al*. (1974), and Van Niekerk *et al*. (1990). However, Viljoen (1996) reported that this system became too expensive. According Engelbrecht *et al*. (2004) hay plays an important part in most fodder-flow programmes. Hay production requires higher financial input than foggage and forage. Because of the high running costs, hay should be used only for high producing animals or when no other grazing is available. Hay is usually fed in the winter months, before the veld is ready for grazing (Van Zyl, 2006).

Hay can also be used as a drought reserve. Hay from planted pasture is of much higher quality than that from veld, especially legume hay. Considerable improvements are possible in the growing of hay by using good seed of locally proven cultivars, careful cultivation, fertilization and better irrigation, where appropriate (Tainton 2000).

2.2.4 Silage

A fourth alternative for conserved roughage is silage. Silage is fermented, high-moisture stored fodder which can be fed to ruminants or used as a biofuel in anaerobic digesters. It is fermented and stored in a process called ensilage or silaging and is usually made of the entire green plant of grass crops, maize, forage sorghum, pearl millet or other cereals. The equipment and infrastructure necessary for silage production put it out of the reach of the small scale farmer (Anon 2008).

According to Lane (2000), "Little bag silage" (LBS) has been developed in northern Pakistan and in Nepal as a workable system for small holder farmers. A key feature of LBS is that it allows conservation of available fodder in small quantities over a long period of time. Small quantities can be made in small plastic bags like those traditionally obtained at from local shops (Lane, 2000).

2.3 SILAGE MAKING: THE PROCESS AND PRESERVATION

2.3.1 The process of silage making

According to Wilkinson (2005) the production process of silage may be divided into stages, which is forage harvesting, compaction (exclusion of air) and sealing (make sure the container is air-tight). The main aim of compaction is to exclude air, while the aim of sealing the silage is to prevent re-entry and circulation of air during storage.

Where oxygen is in contact with ensiled material for any period of time, aerobic microbial activity occurs and the material decays to a useless, inedible and frequently toxic product (Ba *et al*. 2005). These micro-organisms can be inhibited either by encouraging the growth of lactic acid bacteria or by using chemical additives (Syed Hassan 1999). Losses of primary fermentation acids, amino acids, protein and residual sugars are sustained during the aerobic deterioration of silage; the principal products are carbon dioxide, ammonia and water (Honig and Woolford 1980).

2.3.2 The preservation process during silage making

The preservation of crops by natural fermentation can only be achieved in anaerobic conditions, which implies that the fodder is protected from deterioration and nutrient loss through the process of microbial lactic acid production (Chin 2002). In an anaerobic environment, the generation of bacteria that produce acetic-acid occurs. The bacteria ferment soluble carbohydrates and produce acetic acid that initiates the reduction in pH to set up the fermentation process. As the pH drops below 5.0, the growth of the acetic bacteria is inhibited, and this enhances the development of the acid lactic producing bacteria. Lactic acid is the most desirable acid of the fermentation process (Lemus 2010). It should comprise more than 60% of the total silage organic acids produced to ensure efficient preservation of the silage. The fermentation is the longest of the ensiling process and it continues until the pH is low enough to inhibit the growth of all bacteria. The final pH of the ensiled forage crop will depend on the type of forage being used and their condition at the time of ensiling (Lemus 2010).

The magnitude of fermentation changes is greater where air is relatively more abundant, for example near the surface of the silage (Cook 1973). Although part of the chemistry of aerobic deterioration is not fully understood, the rise in temperature, which usually accompanies the process, is correlated directly to the dry matter loss.

Although a minimum goal is to limit temperature from 27°C to 32°C is acceptable, the respiration by eliminating air (oxygen) trapped in the forage mass. Some air will be incorporated into any silo during the filling process, and a slight increase in silage temperature might occur. This temperature increase can clearly be limited by harvesting at the proper moisture content and by increasing the compaction. It is desirable to limit respiration during the fermentation process by using common sense techniques that include close inspection of the silo walls prior to filling.

2.4 THE INFLUENCE OF CROP CHARACTERISTICS AND EXTERNAL FACTORS ON SILAGE MAKING

According to Wilkinson (2005) there are three characteristics which are important when making silage: dry matter, sugar or water soluble carbohydrate concentration and buffering capacity or resistance to acidification. For a particular crop to have a high ensilability, all three characteristics must be favourable to rapid acidification.

2.4.1 Dry matter content

Wilkiinson (2005) summarised the influence of dry matter content on silage as follows: "The undesirable bacteria prefer wetter condition in the silo. Thus higher dry matter concentration reduces the risk of poor quality fermentation. There is, also a greater chance of a relatively high sugar concentration in a fresh crop, if it is harvested at high dry matter content. Ways of achieving high dry matter contents include delaying harvest until the crop is relatively mature and leaving the crop to wilt in the field between mowing and ensiling".

2.4.2 Sugar

"Micro organisms use water-soluble carbohydrates (WSC) as the main energy source for growth. The main sugars present in plants are fructose, glucose and sucrose. There is only limited fermentation of other carbohydrates in plants such as starch, cellulose and hemicelluloses. The higher the sugar concentration in a crop at harvest, the greater the chances of achieving a good fermentation and a well preserved product. This is especially true if the crop is harvested with a short period of field wilting. Other factors affecting the concentration of sugar are wilt and fertilization. Rapid field wilting is normally reflected in an increase in water soluble carbohydrates concentration, whilst water soluble carbohydrates normally peak, especially on a dry sunny day. Nitrogen normally increases leaf growth and since WSC tends to accumulate in the stem fraction of the grass plant, higher levels of N fertilizer tend to be reflected in reduced concentrations of WSC" (Wilkinson 2005).

2.4.3 Buffering Capacity

According to Wilkinson, (2005), the buffering capacity of forages influences the ease with which the forage can be ensiled. Buffering capacity of forages can be defined as the degree to which forage material resists changes in pH. Forages with a high buffering capacity will be highly resistant to a reduction in pH which is necessary for good preservation. Therefore more acid must be produced to reduce the pH to desired levels. This is undesirable in silage because more water soluble carbohydrates (WSC) must be used to produce the additional acid. Where the buffering capacity is high, it has been estimated that twice the amount of WSC is required to give good fermentation, compared with forages with a low buffering capacity (Wilkinson, 2005).

The organic acids (malic, succinic, malonic and glyceric acid) in forages are mainly responsible for buffering capacity. During the ensiling process these organic acids are degraded by bacteria and are replaced by acids with stronger buffering properties. Plant proteins also increase the buffering capacity of silage (Russel 2010).

2.4.4 Bulk density: Particle size and compaction

The factors that affect silage bulk density are weight and pressure applied during compaction, compaction duration, and layer thickness between loads, filling rate, forage DM content and mean particle size (Ruppel *et al*. 1995). Silage bulk density determines the amount of residual gas in empty space in the forage mass. McDonald *et al*. (1991) pointed out that when particle sizes are smaller than 20 mm - 30 mm, positive effects on the availability of soluble carbohydrates may be noticed and consequently, lactic acid bacteria may be stimulated. According to Orosz[3] (2010, Pers. Comm.) the compaction layer should be maximum of 30 cm (ideal layer 10 cm - 15 cm)

[3] Personal Communication: Szilvia Orosz, Department of Nutrition. University of Szent Istvån, Hungary, Godollo.

and the recommended density of 500 to 750 kg**.** The positive effects of particle size on the fermentation process were more generally observed in higher DM content forages (Mayne 1999).

Forage chopping can alter silage fermentation patterns through altering the extent of plant tissue damage. However in silages with low DM content, particle reduction may increase water activity and effluent losses. It could result in the same overall DM loss, but through different mechanisms (Balsalobre *et al*. 2001).

2.5 THE CHEMISTRY INVOLVED IN PRESERVATION

2.5.1 Water soluble carbohydrates

Tremblay (2008) explain the relatively large amounts of fermentable carbohydrates in the forage are required to assure a sufficient lactic acid production which is the main preservation agent. Stimulation of lactic acid formation is the natural way to preserve good quality silage. This begins with laceration of the crop and release of cell sap containing readily available carbohydrate as substrate for microbial growth. Crops that have low amounts of readily available carbohydrate (water soluble carbohydrates) can benefit from the addition of carbohydrate molasses which provides a growing substrate for lactic acid producing bacteria (Langston *et al*. 1986; McDonald and Whittenbury 1973; Watson and Nash 1960).

Lactic acid also contains almost the same energy as the original crop sugars and it can be fermented by rumen micro-organisms. The speed and efficiency of the natural fermentation process is highly variable, depending on the number of lactic acid bacteria on the crop. The speed and efficiency of the natural fermentation process is highly variable, depending on the number of lactic Acid bacteria on the crop, the particular strains of lactic Acid bacteria, temperature and sugar content of the crop (Kandler 1983). Fructose, glucose, sucrose and fructans are the principal sugars in forage crops, and both sucrose and fructans are rapidly hydrolysed to the component monomers during ensilage. Considerable increase in these sugars follows harvest with 11% to 55% of hemicellulose being broken down (Dewar *et al*. 1963).

2.5.2 Fermentation acids

During silage production crops are cut, chopped and stored in a silo pit or bunker, compacted and sealed. The consolidation and sealing phases are vitally important as the removal of air from the crop allows fermentation rather than oxidation (Nakamanee 1999). The naturally occurring micro-organisms in the crop use sugar in the plant as an energy source and produce acids as the by-product (Donaldson 2001). The major acid in well preserved silage is lactic acid. Badly preserved silage contains large amounts of butyric, acetic and other acids from secondary fermentation with low levels of lactic acid. The level of lactic acid in the silage thus depends on the sugar level of the crop at cutting, the degree of wilting, the quality of sealing and the preservation. Silages with a restricted fermentation will tend to have lower levels of lactic acid .High levels of lactic acid reflect dominance of lactobacillus fermentation (McAllan and Phipps 1977)

2.5.3 Ammonia (NH_3)

According to Wilkinson (2005), the deterioration of silage is caused by the activity of aerobic bacteria and yeasts that determine qualitative and quantitative losses in the product. Hence, the detection of ammonia in silage is an important index of product status of preservation. The simplest and quickest method of control is the determination of pH. When the pH of silage is between 3 and 4 (the AIV method) the decomposition processes (formation of carbon dioxide, ammonia and volatile acids) are lower in the silage and normally the quality is good. When the pH rises, the quality of the silage is lowered, because formation of butyric acid is then common, and ammonia is formed freely (Muck and Cellerino 1990). The rate of ammonia volatilization in silage will be determined by the level of air exchange and the pH of the silage (Johnson *et al*. 1982).

2.5.4 Relevant acids in preservation and role of the micro organisms

Lactic acid (LA)

According to Wilkinson (2005), lactic acid (LA) is the main acid produced by natural micro-organisms in the plant material during silage fermentation. Well preserved silages have high concentrations of lactic acid ranging from 80 to 120 g/kg. Silages which have been wilted or treated with formic acid may have lower levels of lactic acid. Poorly preserved silages have low concentrations of lactic acid, below 50 g/kg, and higher levels of other acids such as acetic and butyric acid. Lactic acid gives an indication of the quality of forage fermentation, being produced almost exclusively by the microbes responsible for good silage fermentation and effective preservation. To make good silage the first essential is to ensure the rapid formation of adequate quantities of lactic acid as soon as possible after the green forage has been ensiled. The development of lactic acids forming bacteria in the ensiled material depends in very large measure on the quantity of suitable food material for the bacteria present (Wilkinson 2005).

Acetic acid

Acetic acids are always present in silage. It impacts a sour taste to the silage and renders it less palatable. The formation of acetic acid cannot be prevented entirely but it can be kept within reasonable limits so that it does not spoil the silage. A definite relation exists between the quantity of acetic acid formed and the moisture content of the ensiled green forage. If the green forage contains too much moisture, excessive quantities of acetic acid are formed and the silage is rendered unpalatable (Orosz 2010).

Butyric acid

Butyric acid sometimes occurs in silage which gives it an unpleasant rancid and putrid smell and is unpalatable. As a rule excessive quantities of butyric acid are formed when a green forage is deficient in sugar, as is the case when legumes or very young plant material are ensiled without the addition of sugar (Donaldson, 2001).

2.5.5 Nitrogenous compounds

Once the herbage is cut, rapid and extensive proteolysis is sustained in grass and legumes silage, caused mainly by plant enzymes activities. However, during ensilaging, proteolysis (the breakdown of proteins into smaller amino acids) continues through the activities of micro-organisms. Indeed, some 60% of protein will fail to survive ensilaging. The significance of proteolysis is that amino acids and protein can undergo considerable changes. Generally the quantity of volatile nitrogen in silage is regarded as an indicator of the extent of de-amination (Mac Pherson and Violante 1966) and this is closely correlated to high pH (Carpintero *et al*. 1969). A rapid fall in pH, for example as result of acid addition or effective inoculants, to the crop during ensiling, will promote proteolysis.

2.6 CRITERIA FOR EVALUATION OF THE NUTRITIONAL VALUE OF SILAGE

2.6.1 Dry matter content

The dry matter (DM) content of plants plays an important role during ensiling. The optimal amount of dry matter of plants is normally 30% to 40%, depending of crop (Anon 2007). According to Wilkinson (2005), it is undesirable to ensile plant material which is too dry. Lactic acid production is inhibited and it is also not possible to compact such forage tightly in the silo, with the result that too much air remains in the forage mass which induces undue heating and consequent reduction in the nutritive value of the silage. In addition, silage made from too dry forage tends to become mould. Silage crops that are mature (over ripe) should go into the silo soon after mowing. If they are damp with dew or rain, the quality of the silage might be better. It is perhaps better to make hay instead of silage the over-dry or over-wilted crops (Wilkinson 2005).

2.6.2 Acid detergent fibre (ADF)

ADF is the portion of fiber that is composed of cellulose and lignin and is related to forage digestibility (energy). As ADF increases, digestibility of forage usually decreases. Forages lower in ADF are usually higher in energy. ADF value of <31% is considered as prime quality and a value of above 41% is consider as low quality (Shaker, 2009). According to Tainton (2000), an average ADF content of 35% for silage can be classified as good, while a content of 25% can be consider as more digestible and 50% low in digestibility.

2.6.3 Neutral detergent fiber (NDF)

NDF is the portion of fiber that is composed of soluble carbohydrates, starch, organic acids, pectin and real protein. NDF is related to feed intake and can be used in ration formulation to predict forage intake or quality. Forages low in NDF is usually of high quality and intake is normally high. Recently nutritionists have been using NDF content much more often than in the past. For example, an NDF of alfalfa hay of about 33% - 37% is considered desirable, 39% to 40% average, and forage quality significantly declines from 41% to 45% or above. According to Shaker (2009), NDF of <40% is considered prime and above 54% of low quality standard.

2.6.4 pH

Low pH in silage is often associated with poor intake, because low pH in the animal reduces cellulolytic activity and depresses intake. Similar to the ammonia N content of the silage, the pH will give a good indication of effective fermentation and storing. The desirable pH range for silage is 3.8 and 4.5. Above a pH 4.5 the risk of deterioration during storing becomes increasingly high (Mac Pherson and Violante 1966). If the dry matter content of the material is high, the pH can be higher than 4.5 and will still produce relative good quality silage.

2.6.5 Crude protein (CP)

According to Wilkinson (2005), crude protein (CP) concentration of silage range between 7% and 20% CP for grain and cereals crops and 12% to 18% CP for grass silage. According to Rutherford and Moughan (2000), the accurate and precise quantification of protein and specific amino acids is of fundamental importance for feed. The darker coloured leafier silages tend to contain relatively higher concentrations of CP (more than 15% DM) than light green or yellowish steamy silages (12% to 15% DM).

2.7 SMALL CONTAINER TECHNIQUES

2.7.1 Little bag silage (LBS)

Lane (2000) describes the principle of LBS as follows: “This technique is targeted at smallholder livestock keepers, with few animals that require additional feed supplement during winter months when no green feed is available. The technique may also be suited to peri-urban farmers with access to green feed and with small numbers of animals to be feed”.

This technique is particularly suited to areas where summer pastures and crop to provide a green material that can be used for silage, and where there is the labour available for processing. Lane (2000) suggested the use of strong high density plastic shopping bags, with a capacity to keep 5 kg chopped green fodder and with no obvious holes in the seams. A key feature of Little Bag Silage is that it allows conservation of available fodder in small quantities over a long period of time. This strongly contrasts with traditional silage making techniques where large amounts of fodder must be harvested and chopped at one time. Thus a small-holder family might be able to conserve a couple of bags of LBS a day over a 100 day growing season, which would allow their milking animal to be fed one bag of LBS a day over a 200 day dry season. This fodder might include leafy grass weeds harvested from the crop fields, terraces and bunds, which could readily be partly air-dried under shelter a little at a time before chopping and ensiling. In Nepal, leaves were progressively removed from maize plants as they commenced to senesce, and these would make excellent LBS (Lane, 2000).

2.7.2 **Bucket Silage**

Plastic drums of about 100 to 120 liters capacity have become popular for making silage as they are convenient for filling, packing, sealing, handling and feeding out of it. (Orosz[4], 2010. Pers. Comm.).

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[4] Personal Communication: Szilvia Orosz, Department of Nutrition. Szent Istvån University, Hungary, Godollo.

CHAPTER 3

MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

3.1.1 Dewagenings drift

The study was conducted in Gauteng Province on Hygrotech's Dewagenings drift Experimental Farm, situated approximately 40 km South-east of Pretoria and 5 km from Moloto village along the R 573 route between Pretoria and KwaMhlanga. The coordinates of the area are S 25°29'0" and of E 028°36'8" and the position is shown on Figure 3.1. The soil varies from sandy to sandy-loam.

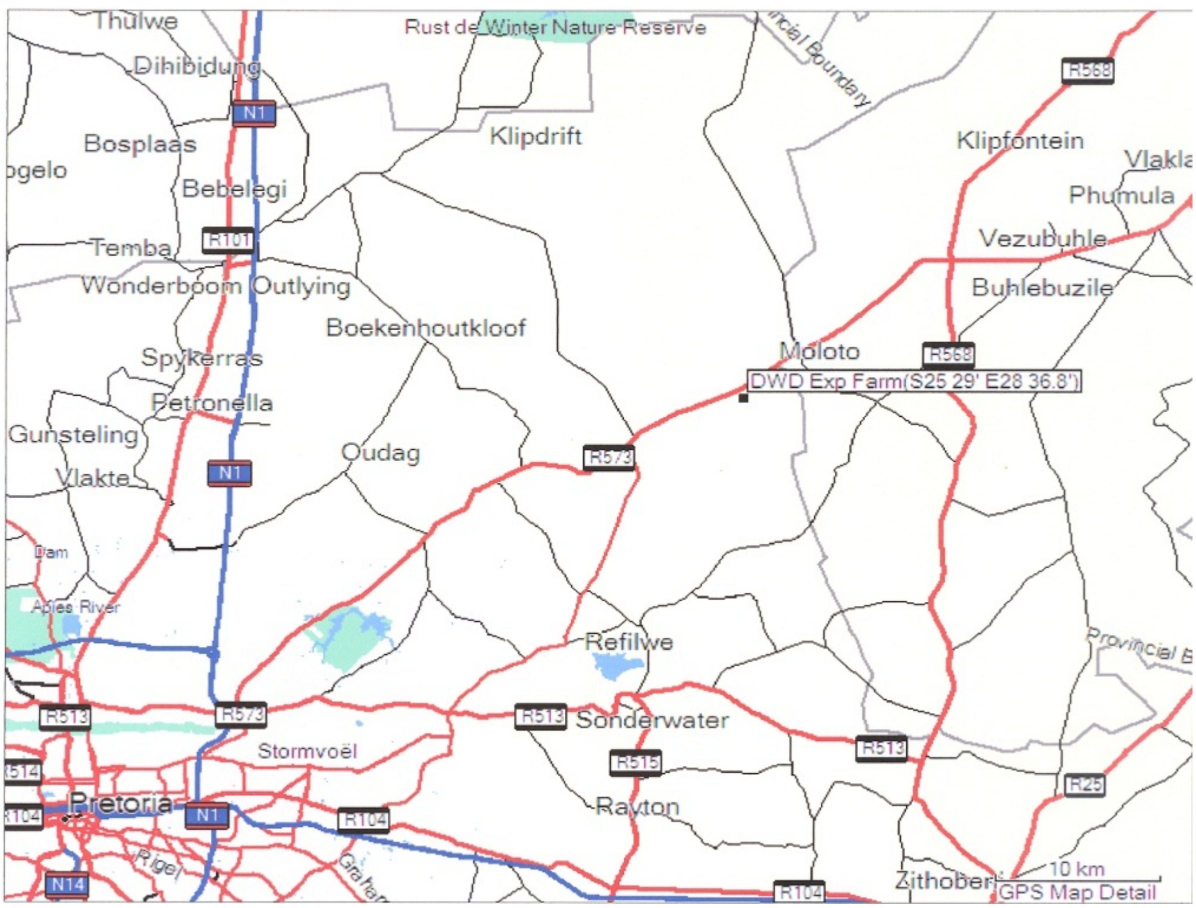

Figure 3.1: Map of Dewagenings drift experimental farm.

3.1.2 Meteorology

The long term average (LTA) meteorological data of the area as measured at the ARC Animal Production Institute, Roodeplaat (20 km from Dewagenings drift) is shown in Table 3.1 (Anon, 2010).

Table 3.1: The long term average (LTA) climatic data at the Animal Production Institute, Roodeplaat

(Source: ISCW, Agromet Section, Private Bag X 79, Pretoria 0001)

	Frost (days)	Rain (mm)	Rel Hum. Min (%)	Rel Hum. Max (%)	Temp Min (ºC)	Temp Max (ºC)
Jan	0.0	140.5	36.9	87.8	17.0	29.7
Feb	0.0	94.7	34.3	88.0	16.6	30.2
Mar	0.0	61.2	34.6	88.0	15.0	29.1
Apr	0.0	28.9	31.8	89.8	11.3	27.0
May	1.3	15.9	25.3	87.3	5.8	24.1
Jun	0.8	9.2	26.2	87.5	3.9	21.7
Jul	3.9	1.9	19.8	82.1	2.3	22.2
Aug	1.0	4.8	19.7	79.2	5.7	24.9
Sep	0.1	6.0	17.4	75.7	9.2	28.2
Oct	0.0	59.9	23.9	79.5	13.5	29.7
Nov	0.0	55.9	30.4	84.8	15.3	29.6
Dec	0.0	83.4	32.4	87.0	16.4	30.1
Annual	7.1	562.3	332.8	1017.6	132.0	326.5

Average first frost: 29 May
Average last frost: 25 August
Average frost season: 58 days
Average frost days per year^{-1}: 7 days
Percentage years with frost: 100.00

According to Table 3.1 frost occurs during the period May to August with the highest intensity in July. Temperatures of below 10^{o}C (LTA) occur from May to September with the lowest of 2.3^{o}C in July. The warmest months are October to March with a long term average ranging from 29.1 - 30.2^{o}C. The LTA rainfall is 562.3 mm per annum and peaks from October to March, with the highest (140.5 mm) in January.

3.2 TREATMENTS AND PROCEDURES

3.2.1 Experimental design

The experiment was laid out in a randomized complete block design (RCBD), in a 4×3 factorial arrangement, with 3 replications for each treatment. The two main treatments studied, during both seasons, were:

a). Crops species

- Forage sorghum (*Sorghum vulgare),* cultivar Kow Kandy
- Pearl millet (*Pennisetum glaucum*), cultivar Hypearl millet
- Maize (*Zea mays*), cultivar SR52
- Buffalo grass (*Panicum maximum*), veld grass

b). Ensiling techniques

- Small plastic bag
- Black refuge plastic bag
- Plastic buckets with lids

3.2.2 Establishment and management before cutting

The crops were planted in a well prepared seedbed, which consist of 60cm rows. Each plot (plot 7.5 m in size) consisted of five rows. The interspacing and intraspacing of crops were 12 cm and 30 cm, respectively. The 3 middle rows were then harvested for the ensiling treatments

3.2.3 Cutting and preparation of silage

During the first season (2009/2010) the samples were collected in a mature stage. During the second season (2010/2011) the samples were collected in different growing stages (soft dough, hard dough and matured stage). In each plot, three middles rows were cut, using a sickle.

The crop material was cut at a height of 10cm. The moisture content depended on the stage at which crop was harvested; the soft dough stage had higher a moisture content and the hard stage resulted in a lower moisture content. The crop material was chopped (estimated size of 3cm - 5 cm), using an electric garden compost cutter (Figure 3.2).

Figure 3.2: Crops chopped using an electric compost cutter.

The chopped material was packaged, using ensiling techniques as discussed in 3.2.4.

3.2.4 Ensiling techniques and procedures

- Little bag silage

Finely chopped planted material (in the grass treatment, material was not chopped) was placed in normal shopping bags and the air was squeezed out by hand as explained in Chapter 2, described by Lane (2000) and illustrated in Figure 3.3.

Figure 3.3: Little bags silage making

➢ Plastic buckets with lids

Finely chopped plant material (in the grass treatment, material was not chopped) was placed in 5 ℓ plastic buckets. Air was squeezed out and material was compacted by trampling it, as describe by Orosz et al 2008 and illustrated in Figure 3.4.

Figure 3.4: Plastic buckets silage making

➢ Black bags

Approximately two kilogram of finely chopped plant material (in the grass treatment, material was not chopped) was placed in standard black refuse bags. The air was squeezed out by putting it in the ground, covering it with soil from the bottom upwards and then closing it.

3.2.5 Planting dates

First season : 18th November 2009 for forage sorghum, pearl millet and maize.
Second season: 5th January 2011 for forage sorghum, pearl millet and maize.

3.2.6 Harvesting dates

First Season

- 4th March 2010: Harvesting *Panicum maximum.*
- 17th March 2010: Harvesting maize, forage sorghum and Pearl millet.

Second Season

- 27th March 2011: Harvested *Panicum maximum*.
- 20th April 2011: Harvested maize, forage sorghum and Pearl millets (soft dough stage).
- 19th May 2011: Harvested maize, forage sorghum and Pearl millet (hard dough stage).
- 06th July 2011: Harvested maize, forage sorghum and Pearl millet (matured stage).

3.3 Data collection

3. 3. 1 Chemical analysis

After 6 weeks silage were sent in a wet form (in the containers) for chemical analysis. The chemical analysis was done according to the Van Soest (1965) method by the accredited Feed laboratory of the KwaZulu Natal Department of Agriculture and Environmental Affairs. When reading these results, it should be remembered that it is hand cut samples which might influence the values (De Waal, 1990). According to Kalu and Fick (1983) and Fick and Mueller (1989), the crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) are parameters for considering silage quality.

3.4 Data analysis

Treatment effects as well as their interactions were compared, via analysis of variance at $P \leq 0.01$ and at $P \leq 0.05$ levels of testing. The difference between the means was separated through the Fisher's protected least significance difference procedure. The species and techniques were compared against each other using analysis of variance and the Fischer's protected LSD within one season, but separately for the two seasons (2009/10 and 2010/11). Data was analysed using the statistical program GenStat® (Payne *et al*. 2009).

CHAPTER 4
RESULT AND DISCUSSION

4.1 INTRODUCTION TO RESULTS

The aim and objectives of this study (In Chapter 2) were mentioned to evaluate the nutritional value of silage made from different crops, with different ensiling techniques, to be used by small scale farmers.

4.1.1 Species used:

- Forage sorghum (*Sorghum vulgare)* cultivar Kow Kandy
- Pearl millet (*Pennisetum glaucum*) cultivar Hypearl millet
- Maize (*Zea mays*) cultivar SR52
- Buffalo grass (*Panicum maximum*) veld grass

4.1.2 Ensiling techniques (Chapter 3, Paragraph 3.2.2):

- Small plastic bags
- Buckets with lids
- Black plastic bags

4.1.3 Nutritional parameters

The nutritional parameters that were used to describe the quality of silage with different treatments were:

- Dry matter
- Acid detergent fiber (ADF)
- Neutral detergent fiber (NDF)
- Ammonia (NH_3)
- Lactic acid (LA)
- pH
- Crude protein (CP)

All parameters were measured at least six weeks after ensiling, on a wet matter basis.

The following set of norms to evaluate silage quality was compiled from available literature (Bal *et al*. 2009, McDonald *et al*. 1991 and Orosz, 2010) and personal communication with Orosz[5] (2012).

1. Dry matter: The ideal DM content for maize silage should be between 35% and 38% and not lower than 30% and for sorghum: 30% - 32%. Too dry material cannot be compacted enough and that leave too much air between the plant material which inhibited lactic acid production and accelerated acetic acid and butyric acid production.
2. ADF: 28% and lower are ideal (an ADF content of up to 35% for silage is also acceptable (Tainton 2000).
3. NDF: 45% is ideal. Higher ADF and NDF in grain sorghum are caused by high grain content, with more starch. (NB: Higher ADF and NDF in silage are not as negative as in green grazing and hay).
4. Ammonia (NH_3): 0.1% to 0.3% if tested as DM and 0.05% if tested as fresh material.
5. Lactic acid: 1.9% to 3.8% (2.5% is ideal for maize silage); this is the most important acid for good fermentation during for silage.
6. pH: optimal range 3.8 to 4.3 is the ideal for maize and 4.5 to 5.0 for legume silage.
7. Crude Protein: Not lower than 7% to 9% in maize silage. 20% to 22 % for legume silage.

[5] Personal Communication: Szilvia Orosz, Department of Nutrition. University of Szent Istvån, Hungary, Godollo.

4.2 FIRST SEASON RESULTS (2009/2010)

The nutritional value of the silage was analysed by the Cedara Feed Laboratory (Department of Agriculture KZN, Pietermaritzburg) and the data were analysed using GenStat® (Payne *et al*. 2009). Results were compared using a Fisher's protected LSD test.

4.2.1 Dry matter (DM) content of silage, after fermentation.

The statistical results are shown in Appendix A1. Species and techniques as main treatments had a significant effect on the DM content (P≤0.001 and P≤0.006). The interaction between species and techniques did not influence the DM content significantly (P≤0.065). However, when comparing results with a Fisher's protected LSD test (LSD = 6.54), differences were visible, as shown in Table 4.1 in different colours.

Table 4.1: The influence of species and ensiling techniques on the DM content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	25. 90	27.04	32.64	**28.53[a]**
Maize	36.84	23.57	35.66	**32.02[a]**
Pearl millet	24.42	19.62	22.81	**22.29[b]**
Forage sorghum	25.68	22.83	24.37	**24.29[b]**
Average	**28.21[a]**	**23.27[b]**	**28.87[a]**	
LSD:	Species = 3.78 Techniques = 3.27 Species × Techniques = 6.54			

The highest DM content (%) was measured with maize ensiled in small plastic bags (36.84%) and buckets (35.66%) and *Panicum maximum*, in buckets, with 32.64% (marked red). A second group with DM contents of 24.37% to 27.04%, marked blue in the table, included *P. maximum* in small bags and buckets. A third group with DM contents that varied between 19.6% and 23.6% (marked yellow in the table), include maize, pearl millet and forage sorghum silage in black plastic bags and pearl millet in buckets. If the norms mentioned in Paragraph 4.1.3 are used as criteria, it can be expected that the treatments (marked in red in table) will result in good quality silage. The DM content of the four different species (main treatment) is shown in Figure 4.1

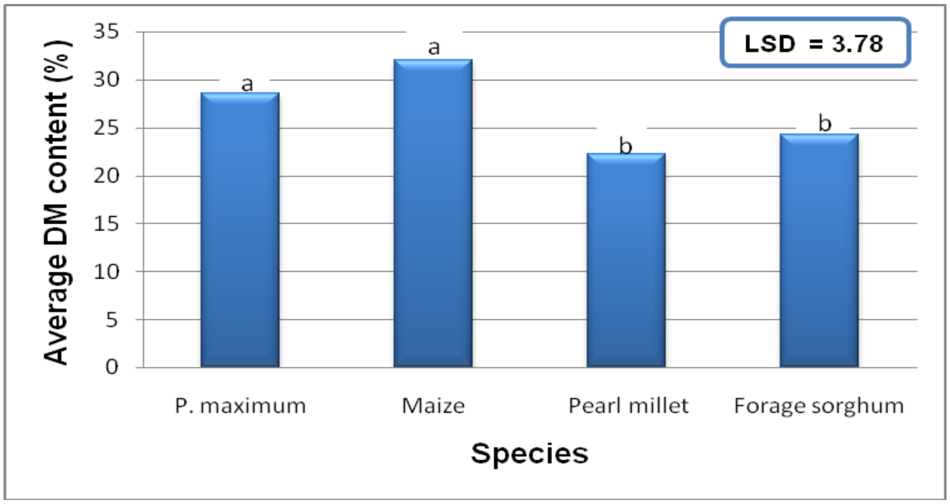

Figure 4.1: The effect of Species on DM content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

The highest average DM content was obtained with maize (32.02%) and *P. maximum* (28.53%) as main treatments. These two DM contents were significantly (LSD = 3.77) higher than the 22.29% of pearl millet and 24.29% of forage sorghum.

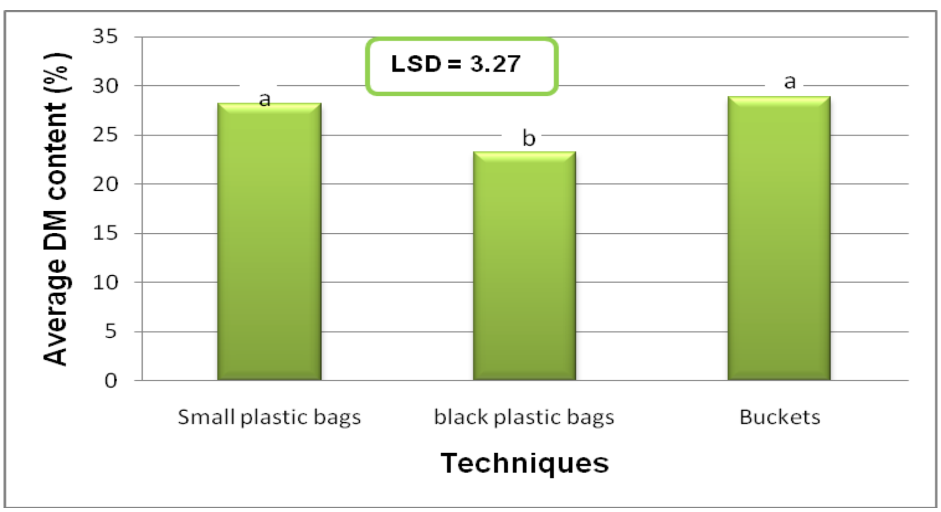

Figure 4.2: The effect of techniques on DM content (%) silage in 2009/10.
(a, b, and c indicate significant differences)

If techniques of ensiling are considered as main effect (Figure 4.2), the highest DM content was obtained in the buckets (28.87%) and small plastic bags (28.21%). They did not differ significantly (LSD = 3.27) from each other, but were significantly higher than the 23.27% of black plastic bags silage.

4.2.2 Acid detergent fiber (ADF) content

The statistical results are shown in Appendix A2. Species and techniques as main treatments had a significant effect on ADF content (P≤0.001 and P≤0.077, respectively). The interaction between the species and techniques did not have a significant effect on ADF (P≤0.469). However, when comparing results with a Fisher's protected LSD of 8.13, differences were visible, as shown in Table 4.2 with different colours.

Table 4.2: The influence of species and ensiling techniques on the ADF content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	54.12	52.75	50.39	**54.42[a]**
Maize	31.82	40.31	34.86	**35.66[c]**
Pearl millet	46.82	49.07	48.24	**48.04[b]**
Forage sorghum	42.29	51.09	46.19	**46.52[b]**
Average	**43.76[b]**	**48.30[a]**	**44.92[b]**	
LSD: Species = 4.69 Techniques = 4.06 Species × Technique = 8.13				

The lowest ADF contents were measured with maize ensiled in small plastic bags (31.82%) and buckets (34.86%) marked yellow in table. Pearl millet and forage sorghum, both in small plastic bags and buckets, and maize ensiled in black plastic bags (marked blue) formed an intermediate group with ADF contents of between 40.31% and 48.24%. *Panicum maximum* ensiled with all techniques, pearl millet and forage sorghum, ensiled in black plastic bags formed the highest group (red in Table 4.2), with ADF contents of 49.02% to 54.12%. According to the norms mentioned in

Paragraph 4.1.3, the ADF content of silage should preferably be 28% and lower, however ADF contents of up to 35% for silage is also acceptable (Tainton 2000).

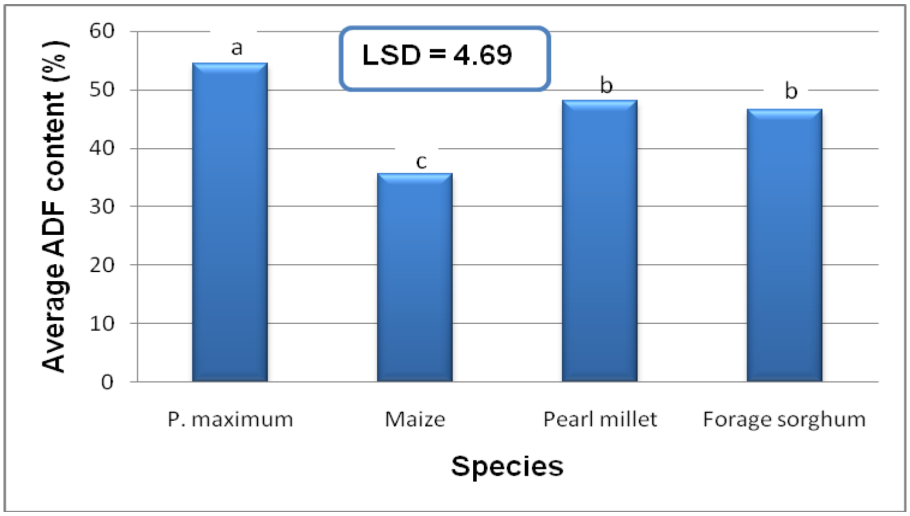

Figure 4.3: The effect of species on ADF content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to the average ADF content of species (Figure 4.3) there was no significant difference between pearl millet and forage sorghum (ADF content of 48.04% and 46.52%, respectively). The average ADF content of *P. maximum* was significantly (P≤0.001) higher than the ADF content of maize, pearl millet and forage sorghum, but pearl millet and forage sorghum did not differ significantly from each other (LSD = 4.69, P≤0.001).

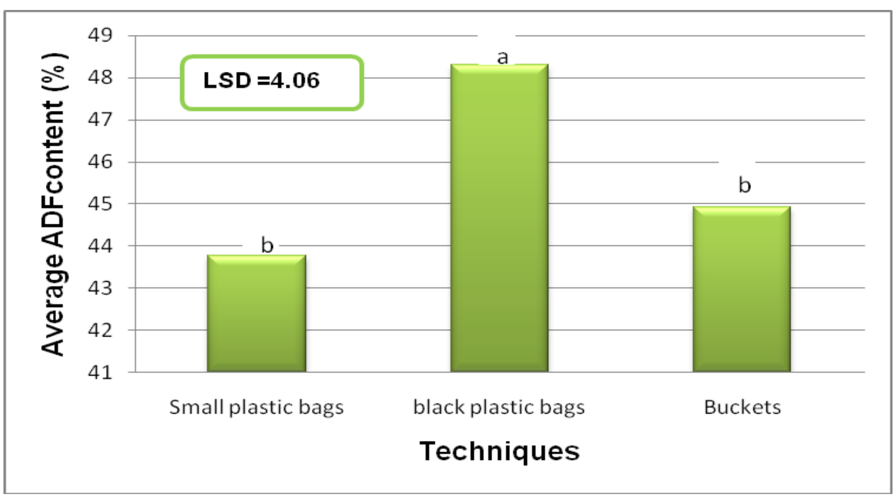

Figure 4.4: The effect of techniques on ADF content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to results in Figure 4.4 the average ADF content of silage obtained in small plastic bags and buckets (43.76% and 44.92%, respectively) did not differ significantly. The average ADF content in black plastic bags (48.3%) was significantly higher than that in small plastic bags and buckets (LSD = 4.06, P≤0.077). These ADF contents fit well in with the norms given in Paragraph 4.1.3.

4.2.3 Neutral detergent fibre (NDF) content

The statistical analyses of the result are shown in Appendix A3. Both species and techniques as main treatments had a significant effect on the NDF content (P≤0.001 and P≤0.077, respectively). The interaction between the species and techniques did not have a significant effect (P≤0.222) on the NDF content. However, when compared with a Fisher's protected LSD of 8.376, differences in NDF contents were visible, as shown in Table 4.3.

Table 4.3: The influence of species and ensiling techniques on the NDF content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	79.82	76.32	77.68	**77.94^{a}**
Maize	60.19	69.01	59.05	**62.75^{c}**
Pearl millet	71.36	74.07	73.9	**73.11^{b}**
Forage sorghum	66.51	75.81	68.33	**70.22^{b}**
Average	**69.47^{b}**	**73.81^{a}**	**69.74^{ab}**	
LSD : Species = 4.84; Techniques = 4.19; Species × Technique = 8.38				

The lowest NDF content was measured (marked yellow) with maize ensiled in small plastic bags (60.19%) and buckets (59.05%). A second group with NDF contents of 66.51% to 69.01% was measured when forage sorghum was ensiled in small plastic bags and buckets and with maize ensiled in black plastic bags. *Panicum maximum* and pearl millet ensiled with all three ensiling techniques and forage sorghum in black plastic bags, showed the highest NDF contents varying from 71.36% to 79.82%.

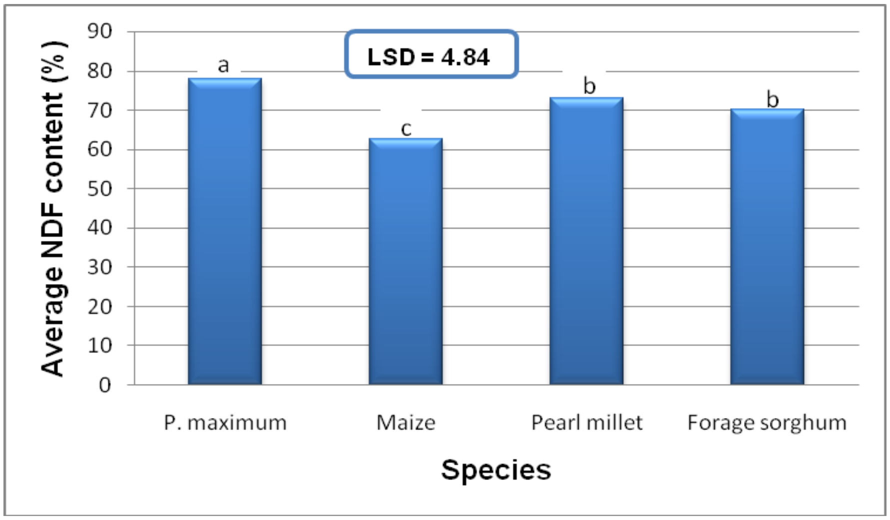

Figure 4.5: The effect of species on NDF content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

In Figure 4.5 the average NDF content for species indicated that forage sorghum and pearl millet (70.22% and 73.11%, respectively) did not differ significantly from each other, but differ significantly (P≤0.001) from that of maize and *P. maximum* (62.75% and 77.94%, respectively) (LSD = 4.84).

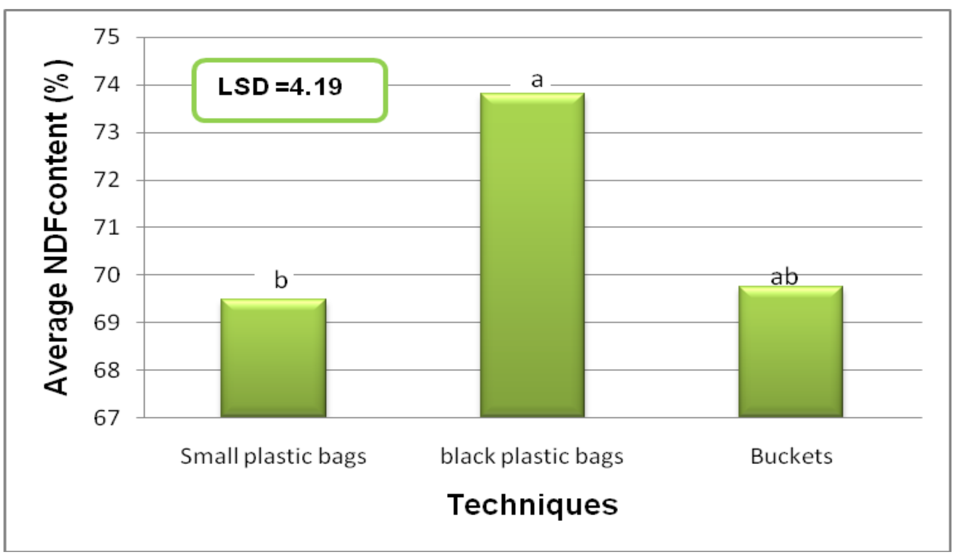

Figure 4.6: The effect of techniques on NDF content (%) silage in 2009/10.
(a, b, and c indicate significant differences)

According to the results in Figure 4.6 the highest NDF content of silage was obtained in black a plastic bags (73.81%), which was not significantly higher (LSD = 4.19) than that in buckets (69.74%). The average NDF content of silage in black plastic bags was significantly higher than that in small plastic bags (LSD = 4.19, P≤0.222. According to the norms mentioned in Paragraph 4.1.3, the NDF content of silage should preferably be 45%. An NDF content of higher than 45% has a negative influence on silage quality.

4.2.4 Ammonia (NH_3) content

According to the statistical analysis shown in Appendix A4, species, as main treatment, influenced the NH_3 content significantly (P≤0.001). Techniques did not have a significant effect (P≤0.931). The interaction between the species and techniques did not have a significant effect (P≤0.259). However, when comparing the results with a Fisher's protected LSD test (LSD =0.01670), differences were visible, as shown in Table 4.4.

Table 4.4: The influence of species and ensiling techniques on the NH_3 content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	0.01	0	0.01	**0.0067[b]**
Maize	0.035	0.025	0.025	**0.0283[a]**
Pearl millet	0.02	0.02	0.025	**0.0277[a]**
Forage sorghum	0	0.015	0.005	**0.0067[b]**
Average	**0.0163[a]**	**0.0150[a]**	**0.0163[a]**	
LSD : Species = 0.00964 Techniques = 0.00835 Species × Technique = 0.01670				

The lowest NH_3 content (marked yellow) was measured when *Panicum maximum* was ensiled in black plastic bags and forage sorghum in small plastic bags and buckets (0%, 0% and 0.0050%, respectively). A second group (marked blue) with intermediate NH_3 contents of 0.0100% to 0.0150% was obtained when *P. maximum* was ensiled in small plastic bags and buckets and forage sorghum in black plastic bags. Maize and pearl millet ensiled with all three ensiling techniques had higher NH_3 contents that varied from 0.0200% to 0.0350%.

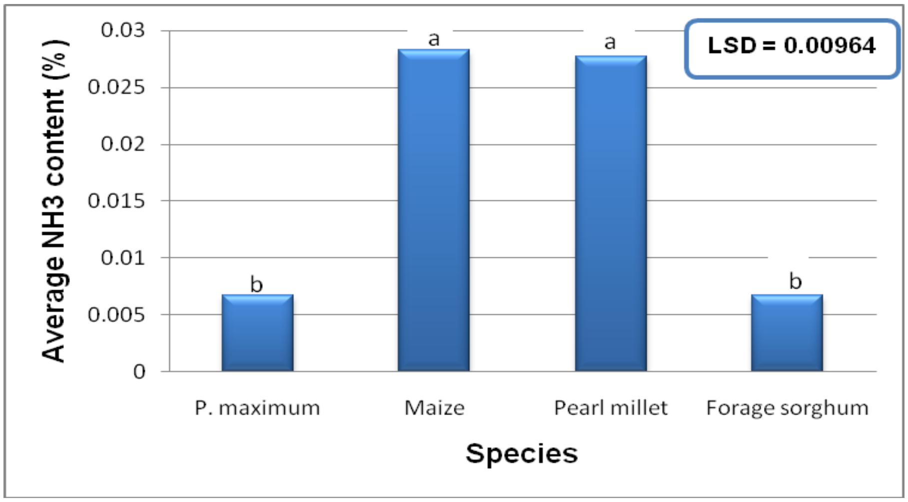

Figure 4.7: The effect of species on NH_3 content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.7, the average NH_3 content of maize and pearl millet (0.0283% and 0.0277%, respectively) did not differ significantly (P≤0.001) from each other. The NH_3 content of *Panicum maximum* and forage sorghum (0.0067% and 0.0067%, respectively) also did not differ significantly from each other. However, *P. maximum* and forage sorghum (both with a NH_3 content of 0.0067%) differed significantly (P≤0.001) from maize and pearl millet (0.0283% and 0.0277%, respectively) (LSD = 0.00964).

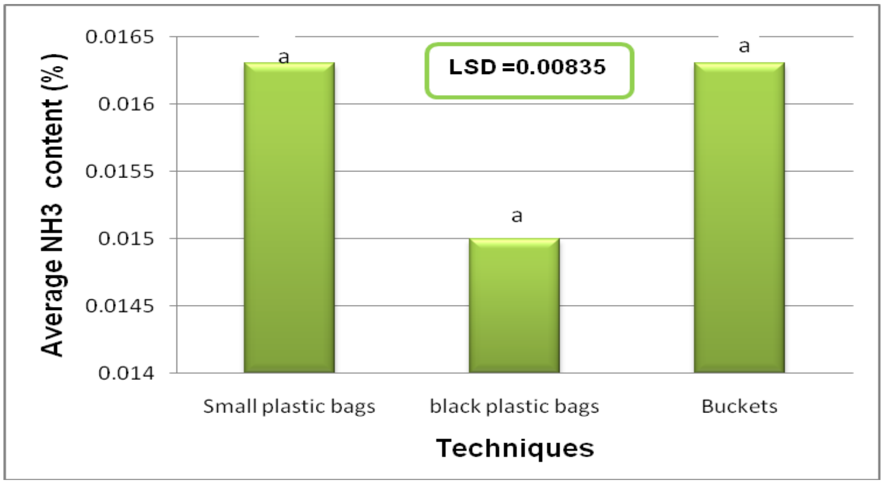

Figure 4.8: The effect of techniques on NH_3 content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.8, the average NH_3 content of silage, obtained with different techniques did not differ significantly (LSD = 0.00835, P≤0.931). According to norms in Paragraph 4.1.3, the preferable NH_3 content should be 0.1% to 0.3%, if tested as DM and, 0.05% (if tested as fresh material).

4.2.5 Lactic acid (LA) content

According to the statistical analysis, shown in Appendix A5, both species and techniques, as main treatments, did not have significant effects on the LA content (P≤0.376 and P≤0.501, respectively). Interaction between the two main treatments did not have a significant effect on the LA content (P≤0.502). However, there were visible differences when compared with a Fisher's protected LSD test (LSD = 0.137), as shown in Table 4.5 in different colours.

Table 4.5: The influence of species and ensiling techniques on the LA content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	0.015	0	0	**0.005^a**
Maize	0.03	0	0.15	**0.060^a**
Pearl millet	0.04	0	0	**0.013^a**
Forage Sorghum	0.005	0	0	**0.002^a**
Average	**0.0163^a**	**0.00^a**	**0.037^a**	
LSD: Species = 0.079 Techniques = 0.069 Species × Technique = 0.137				

Two different groups were identified in Table 4.5. The LA content of the first group (marked blue) varied between 0% and 0.005%. This includes all species that were ensiled in black plastic bags and *P. maximum*, pearl millet and forage sorghum ensiled in buckets. The LA content of the second group that included *P. maximum*, maize and pearl millet, ensiled in small plastic bags (marked red), ranged between 0.015% and 0.040%. According to norms in Paragraph 4.1.3, the preferable lactic acid content should be between 1.9% and 3.8% (ideal 2.5% in maize) .The LA content of silage of all species, in all treatments, was below the ideal LA content.

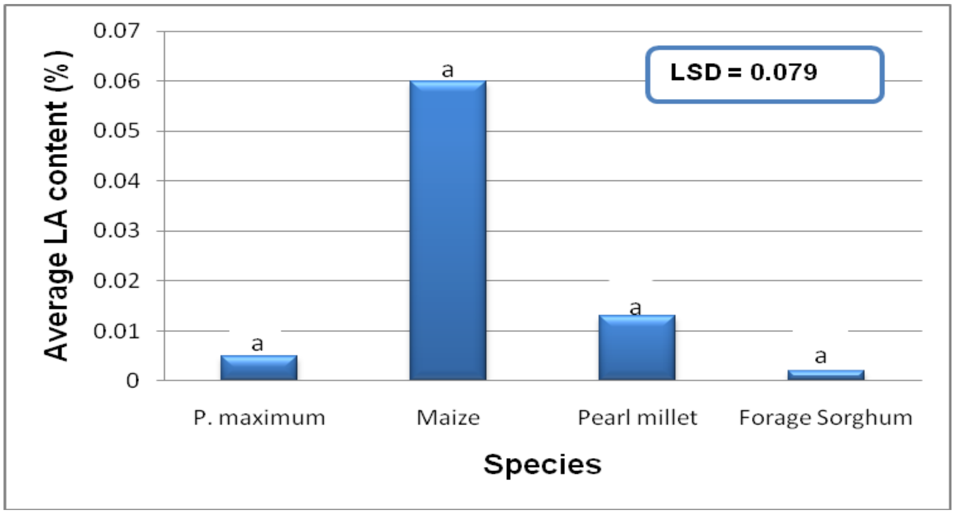

Figure 4.9: The effect of species on LA content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.9, species (*P. maximum*, maize, pearl millet and forage sorghum) did not differ significantly (P≤0.376), in terms of LA content, from each other. The LA content as influenced by ensiling technique, as main treatment, is shown in Figure 4.10.

Figure 4.10: The effect of techniques on LA content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.10, ensiling techniques (small plastic bags, black plastic bags and buckets) did not influence the LA content of silage significantly (P≤0.501).

4.2.6 pH

The statistical analysis in Appendix A6, indicated that both species and techniques as main treatments had significant effects on the pH (P≤0.063 and P≤0.046, respectively). Interaction between the two main treatments did not have significant effects (P≤0.163). However, there were differences when results were compared with a Fisher's protected LSD test (LSD = 2.67), as shown in Table 4.6.

Table 4.6: The influence of species and ensiling techniques on the pH of silage 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	7.88	8.45	7.12	**7.82^{a}**
Maize	4.28	8.52	4.12	**5.64^{b}**
Pearl millet	5.86	7.32	6.38	**6.54^{ab}**
Forage sorghum	7.05	6.42	6.69	**6.72^{ab}**
Average	**6.27^{b}**	**7.68^{a}**	**6.08^{b}**	
LSD: Species = 1.54 Techniques = 1.34 Species × Technique = 2.67				

The highest pH (Table 4.6) developed with *Panicum maximum* at all three ensiling techniques (7.12 to 8.45). Ensiling P*. maximum*, maize and pearl millet in black bags resulted in a pH of 7.32 to 8.45, while forage sorghum in small bags had a pH of 7.05. The lowest pH was measured with maize and pearl millet in small plastic bags and buckets (4.28 and 4.12, respectively). Forage sorghum in black plastic bags and buckets developed a pH of 6.42 and 6.69, respectively. The ideal pH for good silage should be below 5.

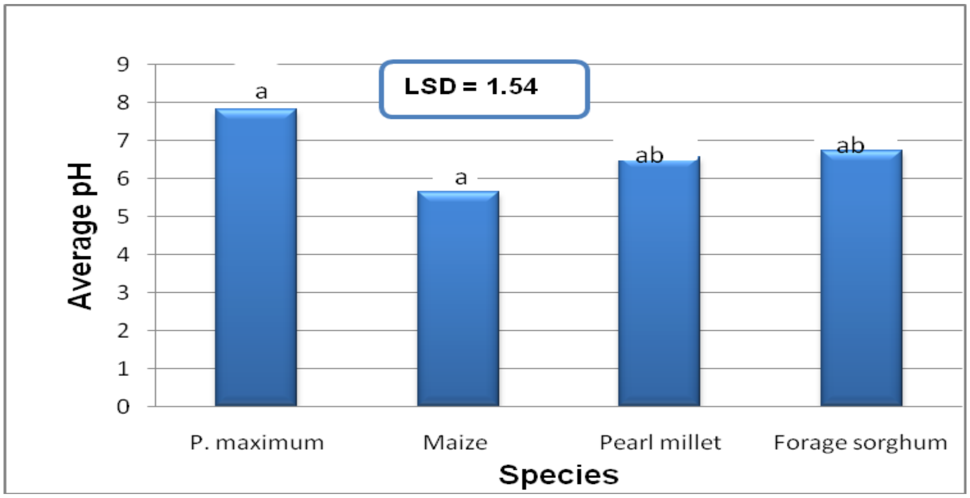

Figure 4.11: The effect of species on the pH of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.11, the average pH of *Panicum maximum* was significantly higher than that of maize. However, it was not significantly higher than that of pearl millet and forage sorghum (6.54 and 6.72) (LSD = 1.54, P≤0.063). The lowest average pH was measured with maize (5.64).

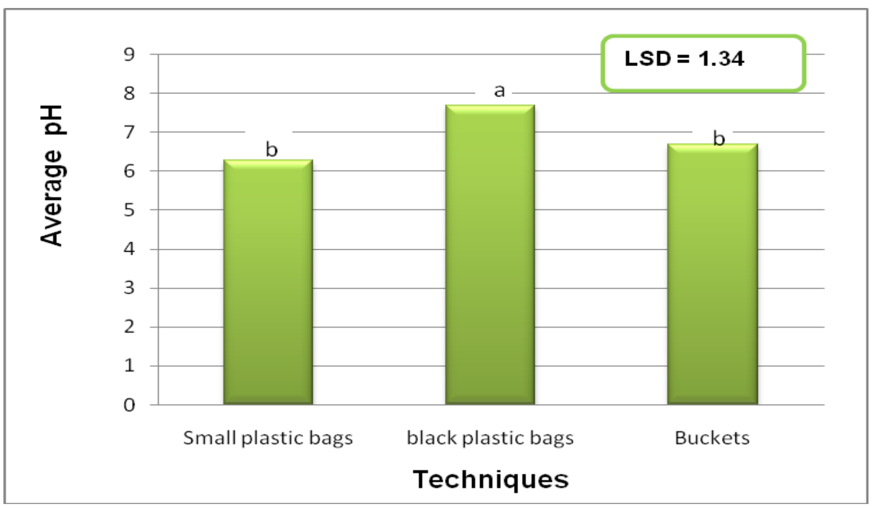

Figure 4.12: The effect of techniques on pH of silage in 2009/10.
(a, b, and c indicate significant differences)

When comparing the average pH, as influenced by ensiling techniques (as main treatment), the effect was significantly higher when ensiled in black plastic bags than the other two treatments (Figure 4.12). The pH of small plastic bags and buckets silage did not differ significantly (6.27 and 6.08, respectively; LSD = 1.34, P≤0.046), but was close to the ideal of 5.0. According to the norms mentioned in Paragraph 4.1.3 the pH of silage should preferably be lower than 5 (4.3 - 4.5 is ideal for maize and forage sorghum silage).

4.2.7 Crude protein (CP) content

The statistical results are shown in Appendix A7. Species and techniques, as main treatments, had a significant effect on the CP content (P≤0.001 and P≤0.064, respectively). The interaction between the species and techniques did not influence the CP content significantly (P≤0.396). However, there was a significant trend when compared with a Fisher's protected LSD test (LSD = 2.23), as shown in Table 4.7, in different colours.

Table 4.7: The influence of species and ensiling techniques on the CP content (%) of silage in 2009/10.

Species	Techniques			Average
	Small plastic bags	Black plastic bags	Buckets	
P. maximum	5.35	6.68	5.06	**5.70[c]**
Maize	11.72	13.02	11.88	**12.21[a]**
Pearl millet	10.35	9.93	10.63	**10.30[b]**
Forage sorghum	10.12	12.35	9.53	**10.67[b]**
Average	**9.39[ab]**	**10.50[a]**	**9.27[b]**	
LSD : Species = 1.29 Techniques = 1.11 Species × Technique = 2.23				

Maize had a CP content of 11.72% to 13.03% (all three techniques), while forage sorghum ensiled in black plastic bags indicated a CP content of 12.35% (marked red in Table 4.7). They did not differ significantly from each other. A second group with an intermediate CP content of 9.53% and 10.63% (marked blue) was obtained when pearl millet was ensiled in all three techniques and forage sorghum ensiled in small plastic bags and buckets. The lowest CP content was obtained with *Panicum maximum* (5.065% and 6.68%) ensiled with all three ensiling techniques (marked red). The only species with CP content lower than 9% was *P. maximum* (all ensiling techniques).

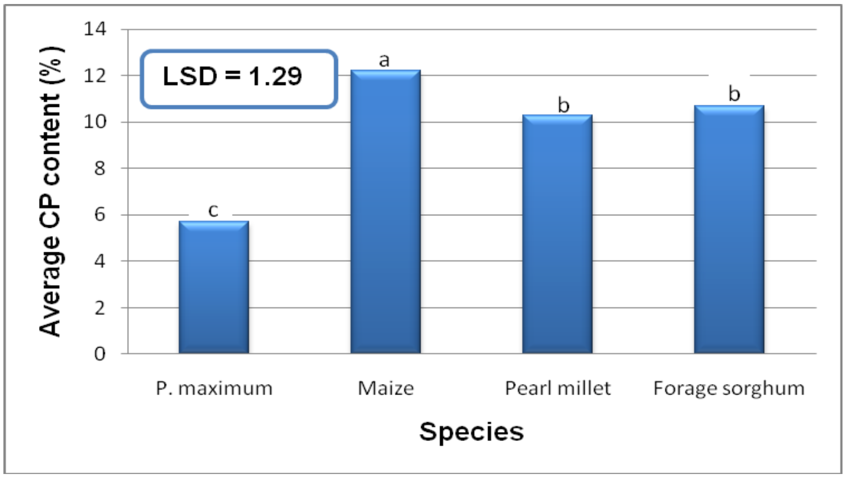

Figure 4.13: The effect of species on CP content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.13, the average CP content for pearl millet and forage sorghum (10.3% and 10.67%, respectively) did not differ significantly different from each other. The average CP content of *Panicum maximum* was significantly different (P≤0.001) and lower than the other species (maize, pearl millet and forage sorghum). The average CP of maize was significantly (P≤0.001) higher (12.21%) than *P. maximum*, pearl millet and forage sorghum. According to the norms mentioned in Paragraph 4.1.3 the CP content of silage should preferably be not lower than 7% and 9%, which indicated that only silage from *P. maximum* was below the standard.

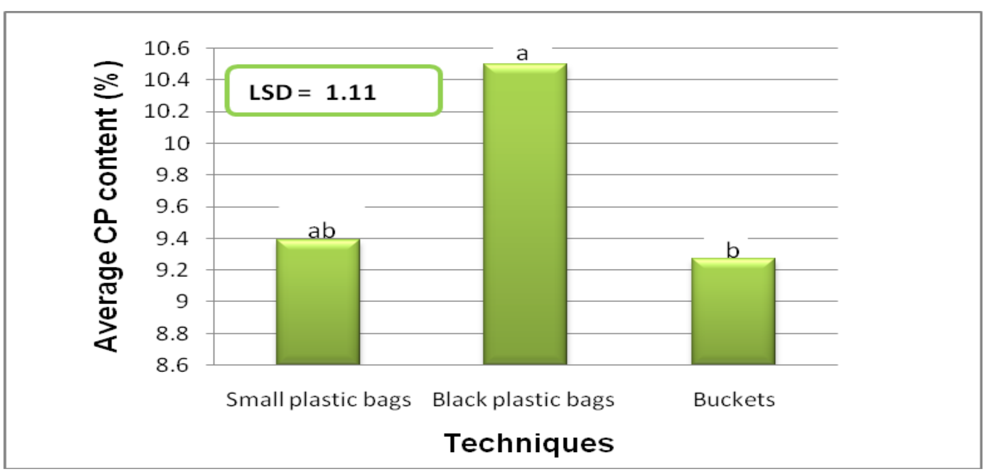

Figure 4.14: The effect of techniques on CP content (%) of silage in 2009/10.
(a, b, and c indicate significant differences)

According to Figure 4.14, the average CP content of silage in small plastic bags did not differ significantly ($P \leq 0.064$) from that in black plastic bags and buckets. However, the CP content of silage in black plastic bags were significantly higher than that in buckets (LSD = 1.11).

4.3 SECOND SEASON RESULTS (2010/2011): SOFT DOUGH STAGE (CUT 1)

The nutritional value of the silage was tested by the Cedara Feed Laboratory (Department of Agriculture KZN, Pietermaritzburg) and the data was analysed using GenStat® (Payne *et al*. 2009). Results were compared, using a Fisher's protected LSD test.

4.3.1 Dry matter (DM) content of silage, after fermentation.

The statistical results are shown in Appendix B1. Both species and techniques, as main treatments, influenced the DM content significantly ($P \leq 0.021$ and $P \leq 0.056$ respectively). The interaction between species and techniques did not have a significant effect ($P \leq 0.767$). However, when compared with a Fisher's protected LSD test (LSD = 10.58), differences were visible, as shown in Table 4.8 in different colours.

Table 4.8: The influence of species and ensiling techniques on the DM content (%) of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	32.8	28.6	**30.70[a]**
Maize	20.7	14.9	**17.80[b]**
Pearl millet	27.1	18.5	**22.80[b]**
Forage sorghum	20.9	19,00	**19.95[b]**
Average	**25.40[a]**	**20.25[b]**	
LSD: Species = 7.48 Techniques = 5.29 Species × Technique = 10.58			

The highest DM content in Table 4.8 (marked red), was obtained with *Panicum maximum* ensiled in small plastic bags and buckets (32.8% and 28.6%, respectively) and pearl millet ensiled in small plastic bags with 27.1%. These three DM percentages were the highest and close to the norms suggested. A second group included silage with a DM content between 18.5% and 20.9% (marked blue), whereas the lowest DM content were obtained with maize ensiled in buckets (marked yellow).

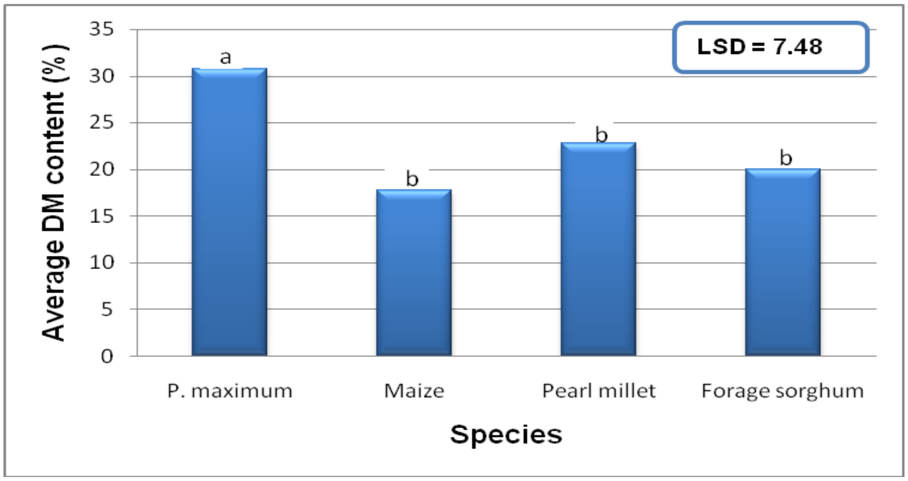

Figure 4.15: The effect of species on Dry matter content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.15, *Panicum maximum* with a DM content of 30.7%, differed highly significantly from other species (maize, pearl millet and forage sorghum (LSD = 7.48 at P≤0.021). However, there were no significant differences between maize, pearl millet and forage sorghum in terms of DM content.

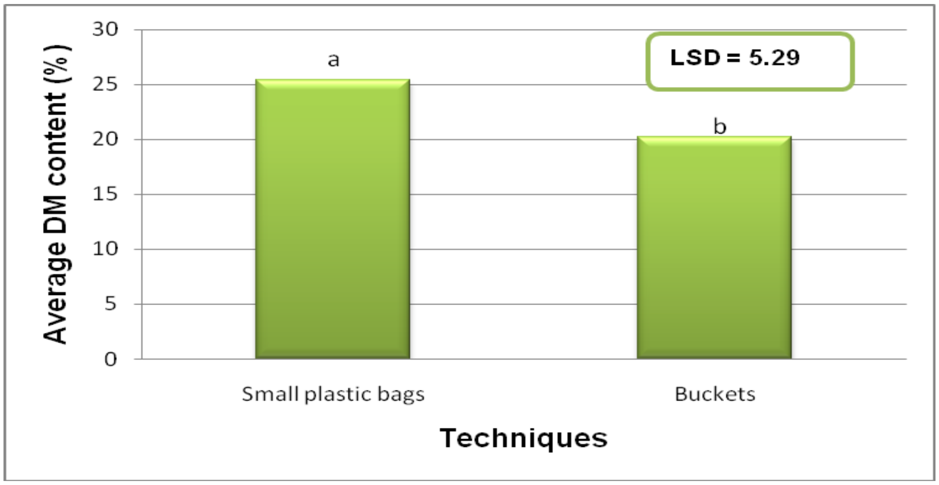

Figure 4.16: The effect of techniques on Dry matter content (%) of Silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.16, the average DM content in small plastic bags (25.40%) differed significantly from buckets (20.25%), (LSD = 5.29, P≤0.056).

4.3.2 Acid detergent fibre (ADF) content

The statistical results are shown in Appendix B2. Species and technique as main treatments did not affect the ADF content significantly (P≤0.741 and P≤0.064 respectively). The interaction between the species and techniques did not have a significant effect (P≤0.111). However, when compared with a Fisher's protected LSD test (LSD = 12.73), differences were visible, as shown in Table 4.9 in different colours.

Table 4.9: The influence of species and ensiling techniques on the ADF content (%) of silage in 2010/11 (Cut 1).

Species	**Techniques**		**Average**
	Small plastic bags	**Buckets**	
P. maximum	54.8	49.0	**51.9[a]**
Maize	49.2	52.2	**50.7[a]**
Pearl millet	42.4	55.8	**49.1[a]**
Forage sorghum	46.7	59.8	**53.2[a]**
Average	**48.3[a]**	**54.2[a]**	
LSD: Species = 9.00 Techniques = 6.37 Species × Technique = 12.73			

Pearl millet and forage sorghum, both ensiled in small plastic bags had the lowest ADF content of 42.4% and 46.7%, respectively (Table 4.9, marked yellow). The intermediate group (marked blue) had an ADF content of between 49% and 55.85% and was obtained when *Panicum maximum* and maize silage were ensiled using both techniques, together with pearl millet silage ensiled in buckets. The highest ADF content of 59.8% was obtained when forage sorghum silage was ensiled in buckets.

According to the norms mentioned in Paragraph 4.1.3, the ADF content of silage should preferably be 28% and lower, however ADF contents of up to 35% for silage is also acceptable (Tainton 2000).

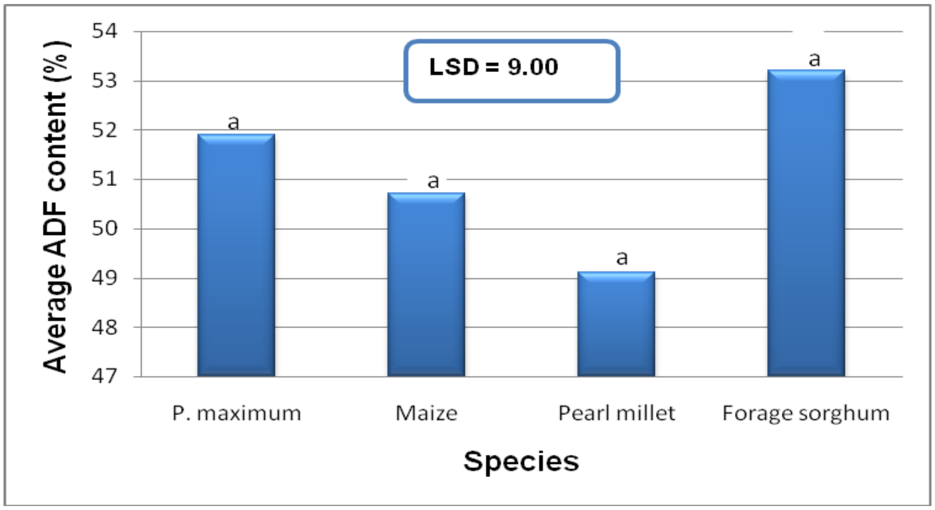

Figure 4.17: The effect of species on ADF content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.17, all species with average the ADF contents 49.1% and 53.2% did not differ significantly (P≤0.733) from one another (LSD = 9.00).

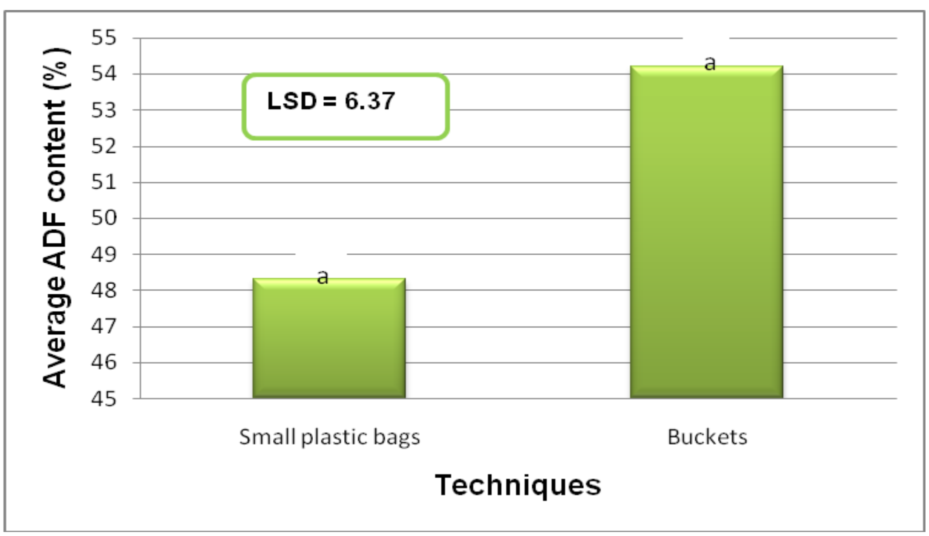

Figure 4.18: The effect of techniques on ADF content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

If techniques of ensiling are considered as the main effect in Figure 4.18, all techniques did not differ significantly (P≤0.064) from one another (ADF contents of 48.3% and 54.2%, respectively).

4.3.3 Neutral detergent fibre (NDF) content

The statistical results are shown in Appendix B3. Both species and techniques as main treatments did not affect the NDF content significantly (P≤0.563 and P≤0.273, respectively). The interaction between species and techniques did not have a significant affect (P≤0.442), as shown in Table 4.10.

Table 4.10: The influence of species and ensiling techniques on the NDF content (%) of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	78.2	72.4	**75.3[a]**
Maize	66.8	71.0	**68.9[a]**
Pearl millet	65.8	74.1	**70.0[a]**
Forage sorghum	68.6	78.7	**73.7[a]**
Average	**69.9[a]**	**74.1[a]**	
LSD: Species = 11.82 Techniques = 8.36 Species × Technique = 16.72			

According to results in Table 4.10, all interaction of species and techniques did not differ significantly (P≤0.442), the NDF contents ranged between 65.8% and 78.7% (marked yellow).

According to Figure 4.19, all species with the average NDF contents ranging between 68.9% and 75.3%, did not differ (P≤0.563) from one another.

According to Figure 4.20, all techniques with the average NDF contents of 69.9% and 74.1%, did not differ significantly (P≤0.273) from one another (LSD = 8.36).

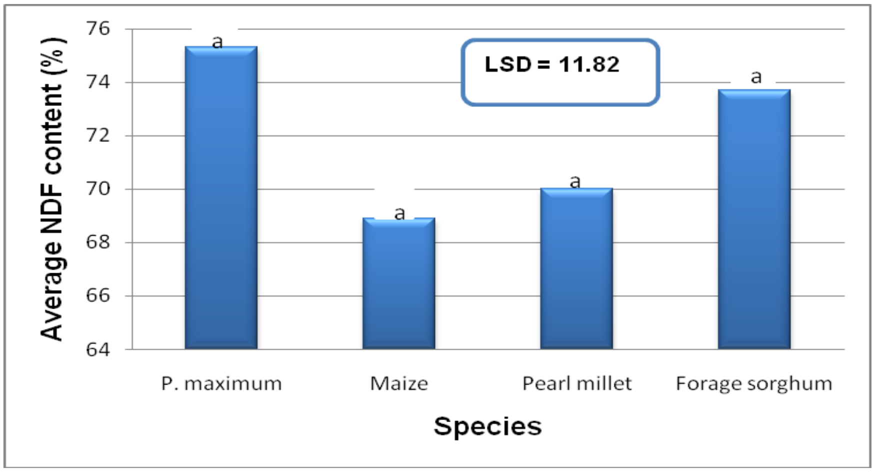

Figure 4.19: The effect of species on NDF content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

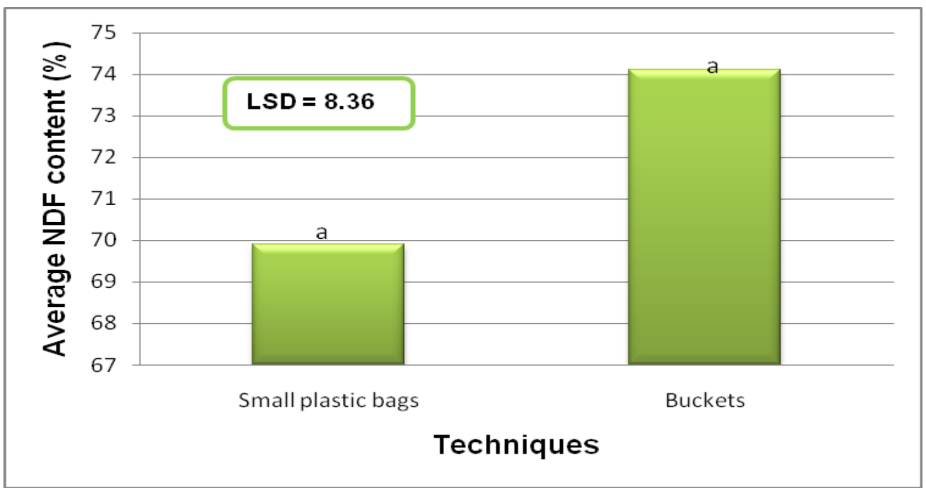

Figure 4.20: The effect of techniques on NDF content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to the norms mentioned in Paragraph 4.1.3, the NDF content of silage should preferably be 45%. An NDF content of higher than 45% has a negative influence on silage quality. Not one treatment was included in this category.

4.3.4 Ammonia (NH_3) content

The statistical results are shown in Appendix B4. Species as main treatment had significant effect (P≤0.010). However, techniques as main treatment had no significant effect on the NH_3 content ($P \leq 0.969$). The interaction between the species and techniques did not differ significantly ($P \leq 0.112$). However, when compared results with a Fisher's protected LSD test (LSD = 0.4417), difference were visible, as shown in Table 4.11.

Table 4.11: The influence of species and ensiling techniques on the NH_3 content (%) of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	0.695	0.29	**0.493^{d}**
Maize	1.005	1.24	**1.123^{a}**
Pearl millet	0.85	1.15	**0.983^{b}**
Forage sorghum	0.92	0.81	**0.865^{c}**
Average	**0.868^{a}**	**0.864^{a}**	
LSD : Species = 0.3123 Techniques = 0.2208 Species × Technique = 0.4417			

The lowest NH_3 content (0.290%) was obtained when *Panicum maximum* silage was ensiled in buckets (Table 4.11, marked yellow). However, the intermediate group (marked blue) was obtained when the *Panicum maximum* silage was ensiled in small plastic bags (0.695%). The highest NH_3 content of 0.81% and 1.24% was obtained when both techniques were used to ensile with maize, pearl millet and forage sorghum silage.

According to Figure 4.21, the average NH_3 content for species indicate that maize (1.123%) is highly significantly different ($P \leq 0.010$) from *Panicum maximum,* pearl millet and forage sorghum (0.493%, 0.983% and 0.865%, respectively, LSD = 0.3123). However, *P. maximum,* pearl millet and forage sorghum were significantly different to each other (LSD = 0.3123).

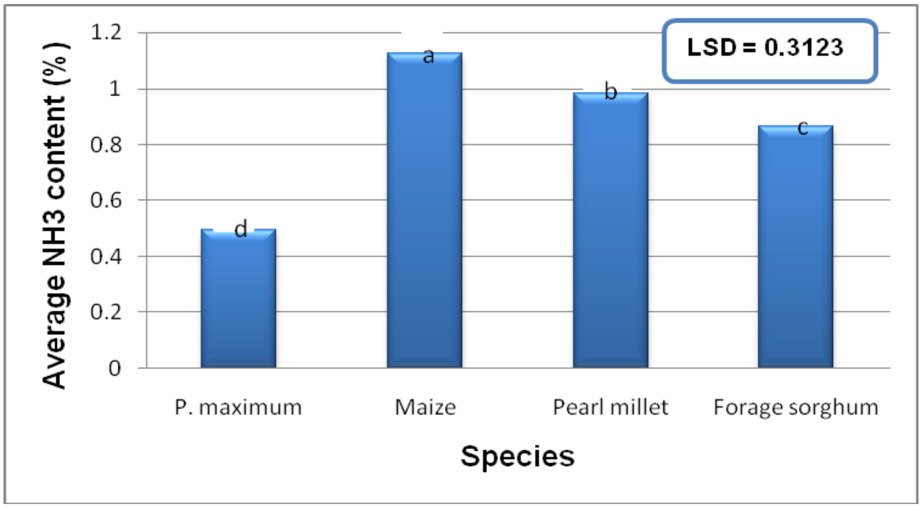

Figure 4.21: The effect of species on NH_3 content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.22, NH_3 content of material ensiled in small plastic bags (0.868%) did not differ significantly (P≤0.969) from silage in buckets (0.864%) ,(LSD = 0.2208). These results were all higher than the preferable NH_3 content of 0.05%, with *P. maximum* ensiled in buckets with lowest content.

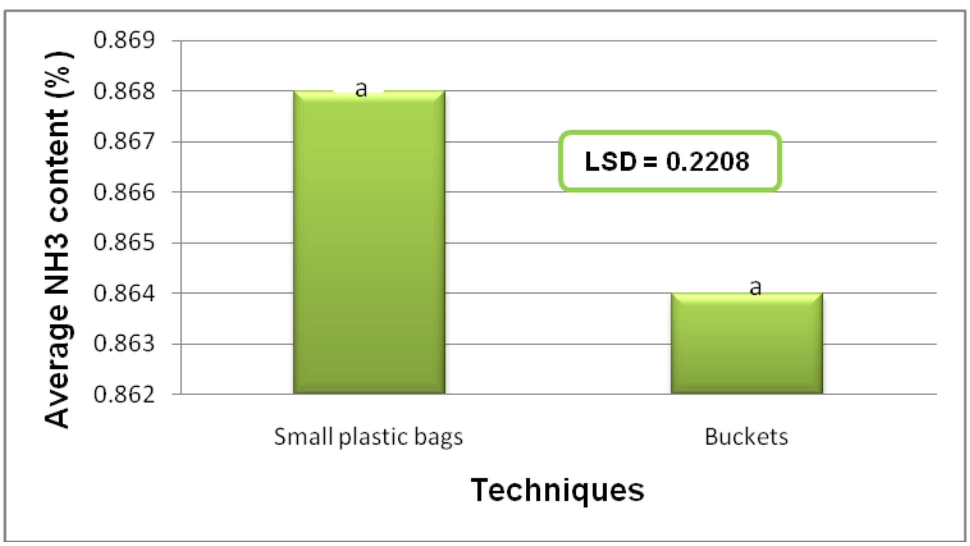

Figure 4.22: The effect of techniques on NH_3 content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

4.3.5 Lactic acid (LA) content

The statistical results are shown in Appendix B5. Both species and techniques as main treatments had significant effect on the LA content ($P \leq 0.042$ and $P \leq 0.007$, respectively). The interaction between the species and techniques did not have significant effects ($P \leq 0.112$). However, when compared with a Fisher's protected LSD test (LSD = 1.926), differences were visible, as shown in Table 4.12.

Table 4.12: The influence of species and ensiling techniques on the LA content (%) of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	0.89	1.21	**1.04^{b}**
Maize	1.89	0.63	**1.26^{ab}**
Pearl millet	0.67	0.14	**0.4^{b}**
Forage sorghum	4.89	0.14	**2.51^{a}**
Average	**2.08^{a}**	**0.53^{b}**	
LSD: Species = 1.362 Techniques = 0.963 Species × Technique = 1.926			

According to results in Table 4.12 the highest LA content of 4.89% was obtained when forage sorghum was ensiled in small plastic bags that were well in the ideal norm of higher than 2.5%. The LA content silage in all other treatments did not differ significantly ($P \leq 0.014$) and ranged between 0.14% and 1.89% that is lower than the preferred content of 2.5%.

According to Figure 4.23, maize silage did not differ significantly from *Panicum maximum*, pearl millet and forage sorghum silage in terms of LA content. However, forage sorghum silage differ significantly ($P \leq 0.042$) from *Panicum maximum* and pearl millet (LSD = 1.362).

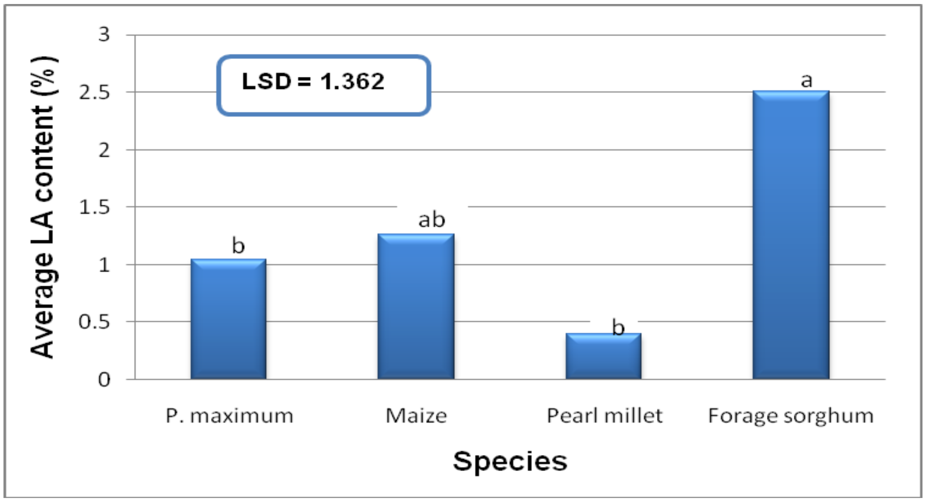

Figure 4.23: The effect of species on LA content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.24, small plastic bags silage differed highly significantly ($P \leq 0.007$) from buckets silage (LSD = 0.963).

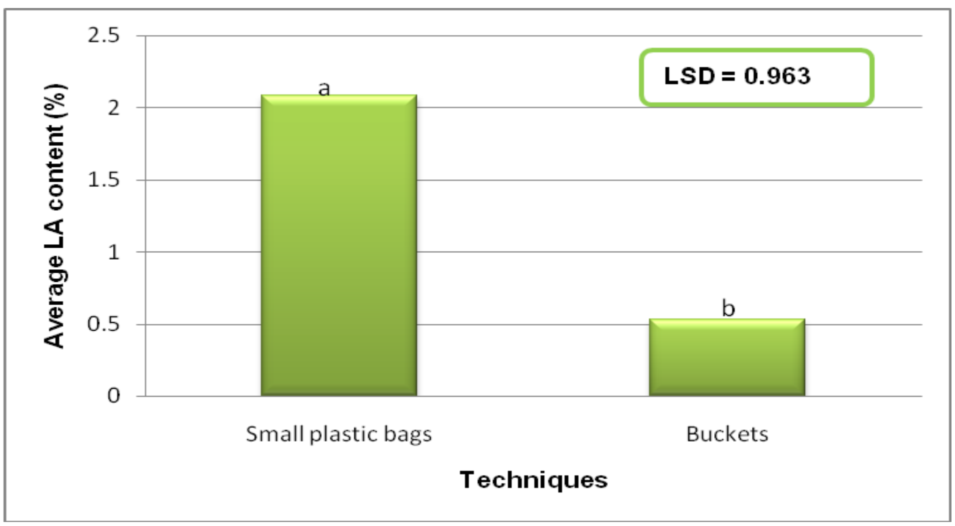

Figure 4.24: The effect of species on LA content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

4.3.6 pH

The statistical results are shown in Appendix B6. Both species and techniques, as main treatments, did not have significant effect on the pH of silage (P≤0.164 and P≤0.678, respectively). The interaction between the species and techniques did not have significant effects on the pH (P≤0.025). However, when compared with a Fisher's protected LSD test (LSD = 2.403), differences were visible, as shown in Table 4.13 in different colour.

Table 4.13: The influence of species and ensiling techniques on the pH of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	8.47	5.4	**6.94[a]**
Maize	7.55	8.53	**8.04[a]**
Pearl millet	8.6	8.71	**8.66[a]**
Forage sorghum	5.85	8.71	**7.28[a]**
Average	**7.62[a]**	**7.84[a]**	
LSD Species = 1.699 Techniques = 1.201 Species × Technique = 2.403			

According to Table 4.13, the highest pH ranged between 8.47 and 8.71 (market red). The intermediate group (marked blue) was obtained when maize was ensiled in small plastic bags (7.55). The lowest pH was obtained when *Panicum maximum* was ensiled in buckets (5.4) and forage sorghum in small plastic bags (5.85) that were the closest to the ideal pH of 5. .

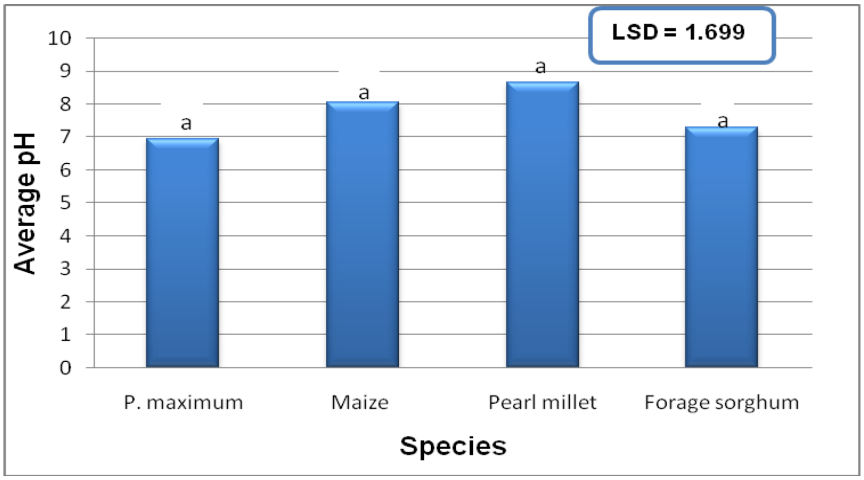

Figure 4.25: The effect of species on pH of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.25, all species had an average pH of 6.94 and 8.66 did not differ (P≤0.164) from one another (LSD = 1.699).

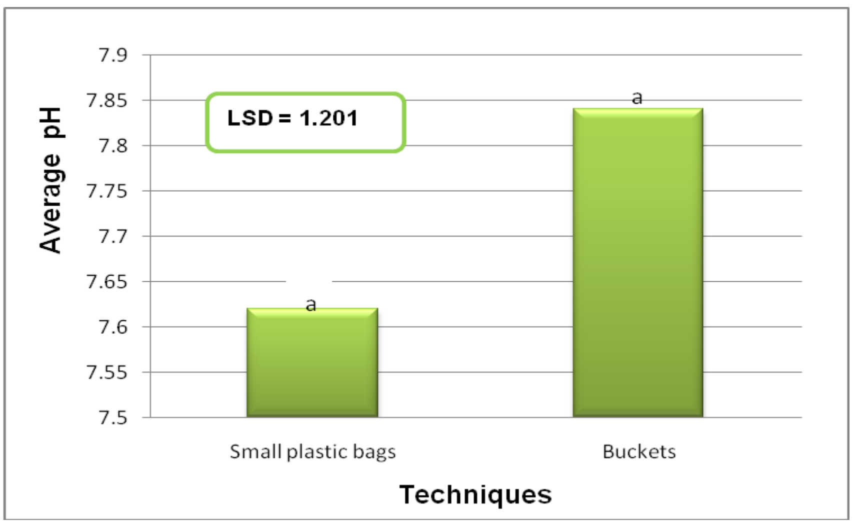

Figure 4.26: The effect of techniques on pH of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

According to Figure 4.26 all techniques did not differ (P≤0.678) from one another (LSD = 1.20). The varied between 7.62 and 7.84.

4.3.7 Crude protein (CP) content

The statistical results are shown in Appendix B7. Both species and technique, as main treatments, influenced the CP content significantly ($P \leq 0.002$ and $P \leq 0.006$, respectively). The interaction between the species and techniques did not have significant effects on the CP content ($P \leq 0.644$). However, there were significant trends when comparing the results with a Fisher's protected LSD test (LSD = 3.532), as shown in Table 4.14 in different colours.

According to results in Table 4.14, the highest CP content of 15.07% was obtained when maize was ensiled in buckets (marked red). An intermediate group (marked blue) was obtained when maize was ensiled in small plastic bags and pearl millet and forage sorghum ensiled with both techniques (10.53% and 14.9%). The lowest CP content (5.86% and 8.27%, respectively) was obtained when *Panicum maximum* was ensiled using both techniques and this silage might influence animal production negatively.

Table 4.14: The influence of species and ensiling techniques on the CP content (%) of silage in 2010/11 (Cut 1).

Species	Techniques		Average
	Small plastic bags	Buckets	
P. maximum	5.86	8.27	**7.06^{b}**
Maize	11.85	15.07	**13.46^{a}**
Pearl millet	10.53	14.9	**12.71^{a}**
Forage sorghum	11.51	13.23	**12.37^{a}**
Average	**9.93^{b}**	**12.87^{a}**	
LSD: Species = 2.498 Techniques = 1.766 Species × Technique = 3.532			

According to Figure 4.27, *Panicum maximum* differed significantly ($P \leq 0.002$) from maize, pearl millet and forage sorghum with an average CP content of 7.06% (LSD = 2.498).

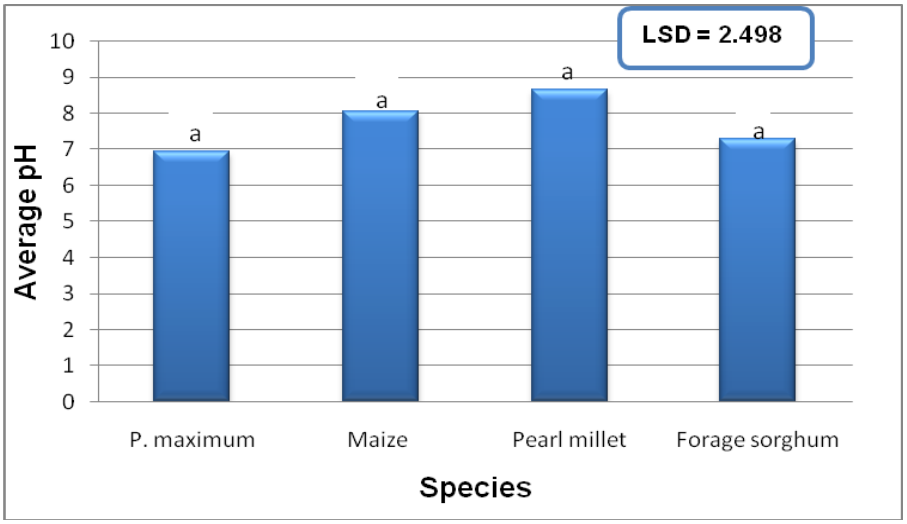

Figure 4.27: The effect of species on CP content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

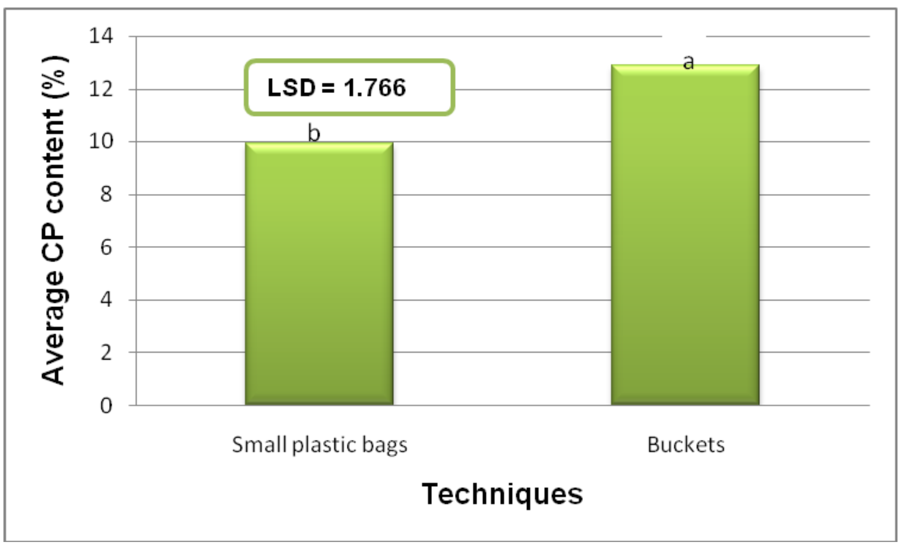

Figure 4.28: The effect of techniques on CP content (%) of silage in 2010/11 (Cut 1).
(a, b, and c indicate significant differences)

If techniques of ensiling are considered as main effect (Figure 4.28), the highest average CP content was obtained with silage in buckets (12.87%) which differed significantly (P≤0.006) from that in small plastic bags (9.93%) (LSD = 1.766).

4.4 SECOND SEASON RESULTS (2010/11) GROWING SEASON: HARD DOUGH STAGE (CUT 2)

The nutritional value of the silage was tested by the Cedara Feed Laboratory (Department of Agriculture KZN, Pietermaritzburg) and the data were analysed using GenStat® (Payne *et al*. 2009). Results were compared by using a Fisher's protected LSD test .During the hard dough stage the *Panicum maximum* was in a dormant stage.

4.4.1 Dry matter (DM) content of silage, after fermentation.

The statistical results are shown in Appendix C1. Both species and technique, as main treatments, as well the interaction between the species and techniques did not influence the DM content of the silage significantly (P≤0.261, P≤0.267 and P≤0.153 respectively) However, when compared with a Fisher's protected LSD test (LSD = 18.15), difference were visible, as shown in Table 4.15 in different colours.

Table 4.15: The influence of species and ensiling techniques on the DM content (%) of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	36.6	31.2	**33.90[a]**
Pearl millet	27.3	30.5	**28.90[a]**
Forage sorghum	29.6	48.4	**39.00[a]**
Average	**31.20[a]**	**36.70[a]**	
LSD	Species = 12.83 Techniques = 10.48 Species × Technique = 18.15		

The highest DM content (marked red) in Table 4.15 was obtained when maize was ensiled in both techniques (36.6% and 31.2%) and pearl millet and forage sorghum ensiled in buckets (30.5% and 48.4% respectively). The DM content of pearl millet and forage sorghum ensiled in small plastic bags was 27.3% 29.6% respectively (marked blue). According to norms in Paragraph 4.1.3, the ideal DM content of silage should be between 35% and 38% and not lower than 30%. Only the silage of pearl millet and forage sorghum, ensiled in small plastic bags, were lower than these norms

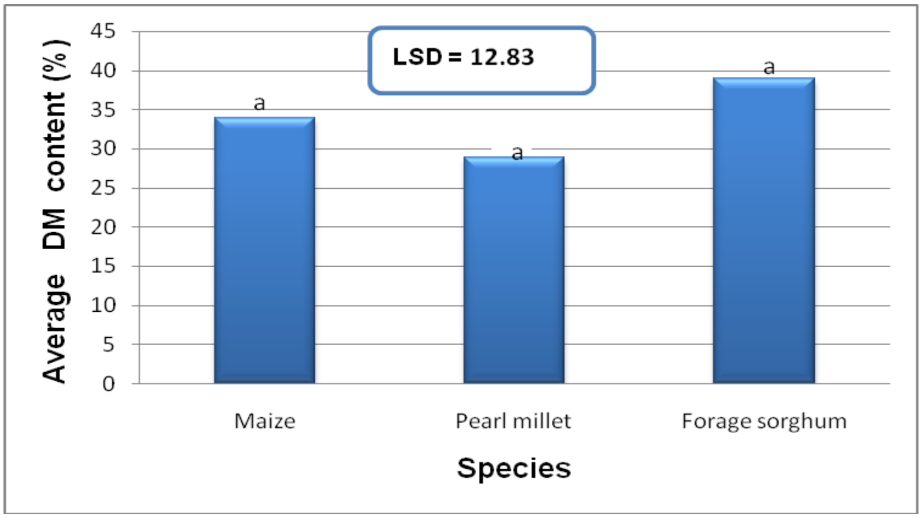

Figure 4.29: The effect of species on Dry matter content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.29, the species with average DM contents (28.9% and 39%, respectively) did not differ significantly from each (LSD= 12.83, P≤0.261).

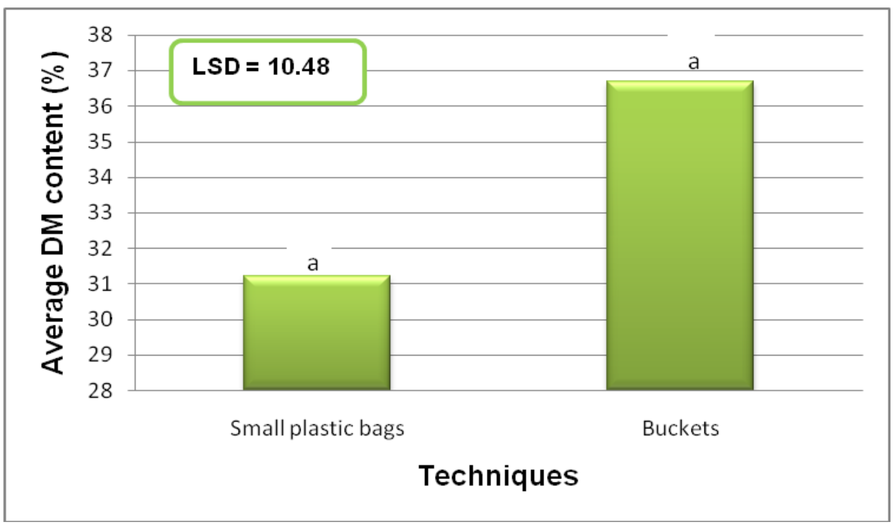

Figure 4.30: The effect of techniques on Dry matter content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.30 the average DM content of Small plastic bags (31.2%) and buckets (36.7%) did not differ significantly when compared with a Fisher's LSD test (LSD = 10.48, P≤0.267).

4.4.2 Acid Detergent Fibre (ADF) content

The statistical results are shown in Appendix C2. The species as main treatment had significant effect on the results (P≤0.033), while techniques, as main treatment, did not have significant effect (P≤0.332). The interaction between the species and techniques did not have significant effects (P≤0.422). However, when compared with a Fisher's protected LSD test of 13.01, differences were visible, as shown in Table 4.16 in different colours.

According to Table 4.16, the lowest ADF contents of 35.5% to 39.6% were obtained when maize was ensiled with both techniques and forage sorghum ensiled in buckets (marked yellow). The intermediate group (marked blue), with an ADF content of 42.1% and 46%, was obtained when pearl millet was ensiled in the buckets and forage sorghum silage in the small plastic bags respectively. The highest ADF content (53.1%) was obtained when pearl millet was ensiled in the small plastic bags (LSD of 13.01, P≤0.422).

Table 4.16: The influence of species and ensiling techniques on the ADF content (%) of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	36.5	39.6	**38.1^{b}**
Pearl millet	53.1	46.2	**49.6^{a}**
Forage sorghum	42.1	35.6	**38.8^{b}**
Average	**43.9^{a}**	**40.5^{a}**	

LSD: Species = 9.20
Techniques = 7.51
Species × Technique = 13.01

According to the norms mentioned in Paragraph 4.1.3, the ADF content of silage should preferably be 28% and lower, however ADF contents of up to 35% for silage is also acceptable (Tainton 2000). The ADF of maize and forage sorghum, in buckets are the nearest to these norms. The ADF content of the three different species (main treatment) is shown in Figure 4.31.

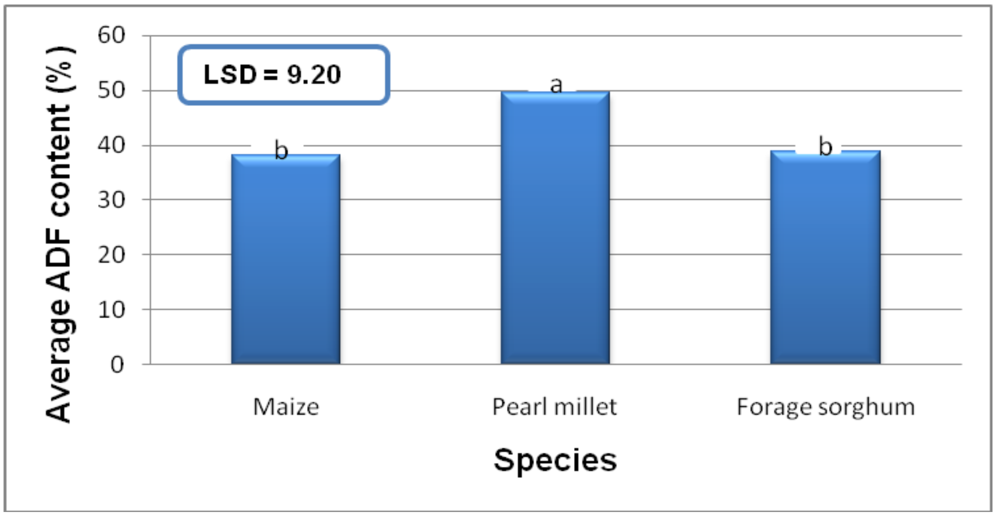

Figure 4.31: The effect of species on ADF content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.31, pearl millet is highly significant difference from maize and forage sorghum (LSD = 9.20, $P \leq 0.033$). However, maize and forage sorghum did not differ significantly with ADF contents of 38.1% and 38.8%, respectively.

According to Figure 4.32 , all technique with the average ADF contents of 43.9% and 40.55%, respectively, differed significantly ($P \leq 0.332$) from each other (LSD = 7.51).

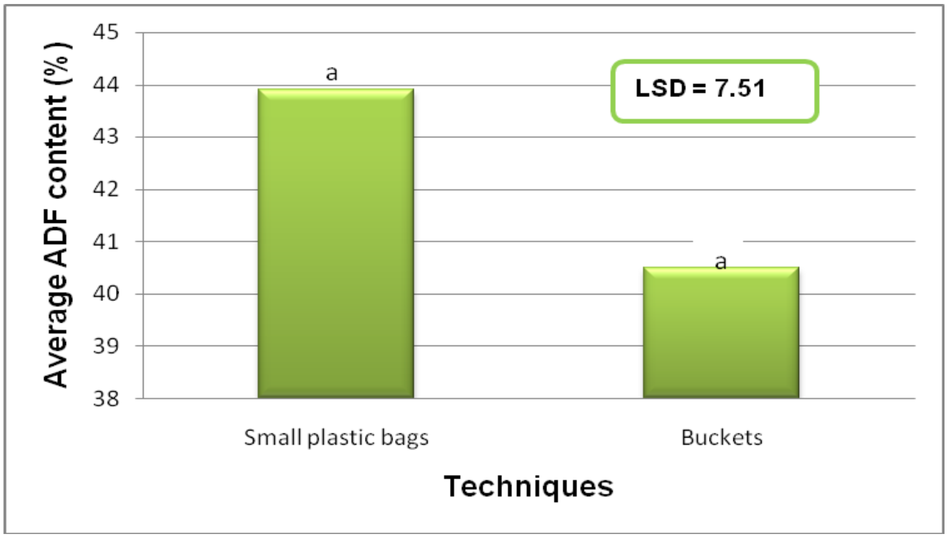

Figure 4.32: The effect of techniques on ADF content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

4.4.3 Neutral detergent fibre (NDF) content

The statistical results are shown in Appendix C3. Both species and techniques (as main treatments), as well as the interaction between species and techniques did not influence the NDF content significantly (P≤0.142, P≤0.900 and P≤0.615 respectively).

Table 4.17: The influence of species and ensiling techniques on the NDF content (%) of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	57.1	57.9	**57.5[a]**
Pearl millet	65.5	71.8	**68.7[a]**
Forage sorghum	60.9	55.7	**58.3[a]**
Average	**61.2[a]**	**61.8[a]**	
LSD: Species = 12.71; Techniques = 10.37; Species × Technique = 17.97			

According to results in Table 4.17 the NDF content of all treatments were above 45% and varied between 55.7% and 71.8%. According to the norms mentioned in Paragraph 4.1.3, the NDF content of silage should preferably be lower than 45%.

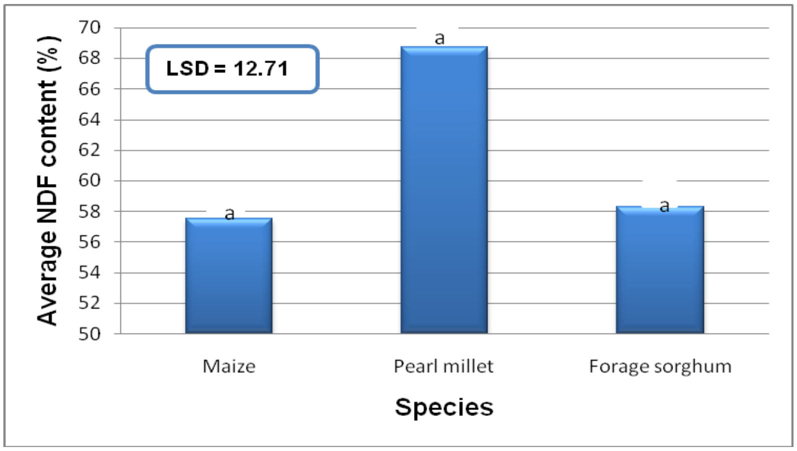

Figure 4.33: The effect of species on NDF content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.33, the average NDF content of the species varied from 57.5% to 68.7% and did not differ significantly (P≤0.142) from each other (LSD = 12.71).

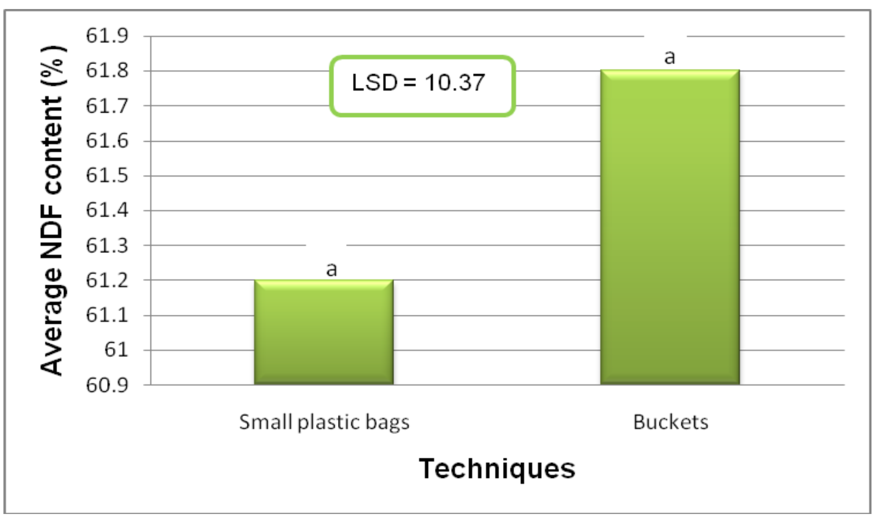

Figure 4.34: The effect of techniques on NDF content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.34, the average NDF content of the two ensiling techniques (61.2% and 61.8%, respectively), did not differ significantly (P≤0.900) from each other (LSD = 10.37).

4.4.4 Ammonia (NH_3) content

The statistical results are shown in Appendix C4. Species (as main treatment) and the interaction between species and techniques did not influence the NH_3 content significantly (P≤0.528 and P≤0.630 respectively). However, techniques, as main treatment, influenced the NH_3 content significantly (P≤0.045). However, when results were compared with a Fisher's protected LSD test (LSD = 0.5323), differences were visible, as indicated in Table 4.18 in different colours.

Table 4.18: The influence of species and ensiling techniques on the NH_3 content (%) of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	0.523	0.383	**0.453[a]**
Pearl millet	0.747	0.407	**0.577[a]**
Forage sorghum	0.617	0.147	**0.382[a]**
Average	**0.629[a]**	**0.312[b]**	
LSD : Species = 0.3764 Techniques = 0.3073 Species × Technique = 0.5323			

According to Table 4.18, the lowest NH_3 content (market yellow) of 0.147% was obtained when forage sorghum was ensiled in buckets (the nearest to the preferable norm). NH_3 contents varying between 0.383% and 0.617% (blue in table) were obtained with maize ensiled with both techniques, pearl millet in buckets and forage sorghum in small plastic bags. The highest NH_3 content (marked red) of 0.747% was obtained when pearl millet was ensiled in small plastic bags (LSD = 0.5323, P≤0.630).

According to Figure 4.35, the average NH_3 content of species (as main treatment) with did not differ significantly (P≤0.528, LSD = 0.3764) from each other (0.382% to 0.577%).

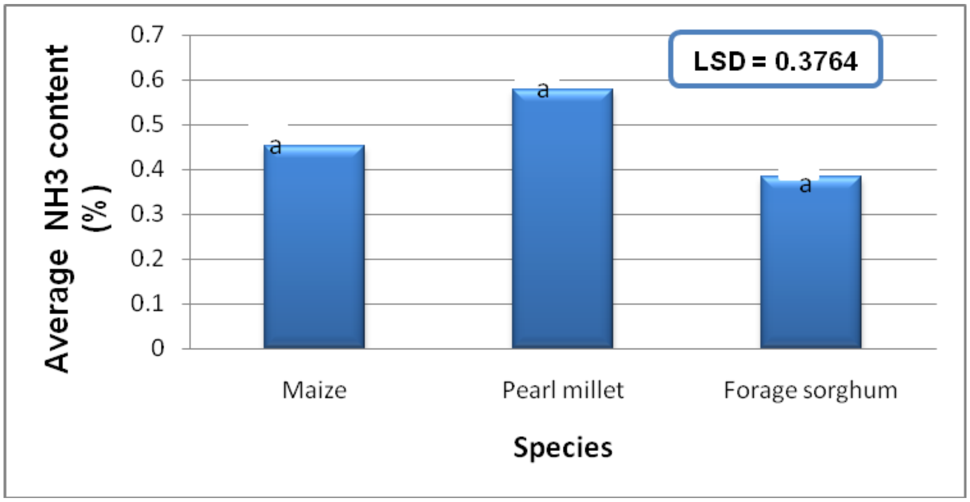

Figure 4.35: The effect of species on NH_3 content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.36, NH_3 content in small plastic bags (0.629%) was significantly higher (P≤0.045) than that in buckets (0.312%).

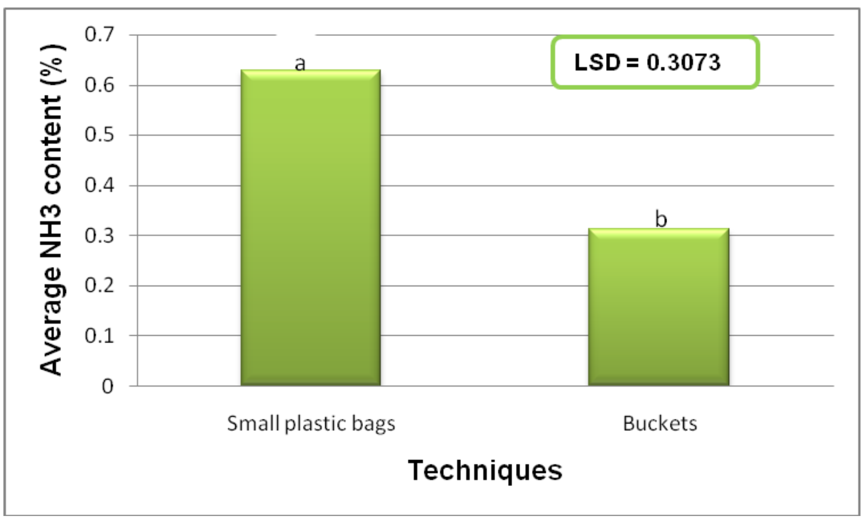

Figure 4.36: The effect of techniques on NH_3 content (%) silage in 2010/11(Cut 2).
(a, b, and c indicate significant differences)

4.4.5 Lactic acid (LA) content

The statistical results are shown in Appendix C5. Species and techniques (as main treatments), as well as the interaction between the species and techniques, did not influence the LA content significantly (P≤0.259, P≤0.922 and P≤0.302 respectively).

However, when results were compared with a Fisher's protected LSD test (LSD = 3.199), differences were visible, as indicated in Table 4.19 in different colours.

Table 4.19: The influence of species and ensiling techniques on the LA content (%) of silage in 2010/11(Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	4.11	2.51	**3.31[a]**
Pearl millet	0.84	2.55	**1.70[a]**
Forage sorghum	3.34	2.99	**3.17[a]**
Average	**2.77[a]**	**2.68[a]**	
LSD: Species = 2.262 Techniques = 1.847 Species × Technique = 3.199			

According to results in Table 4.19, maize ensiled in small plastic bags had the highest LA content of 4.11% (marked red). The LA content of all three species ensiled in buckets and forage sorghum ensiled in small plastic bags varied between 2.51% and 3.34% (marked blue in table, that did not differ significantly (P≤0.302) from each other. The lowest LA content (0.84%) was obtained when pearl millet ensiled in small plastic bags (marked yellow) and was the only treatment with a lower than suggested norm of 1.9%.

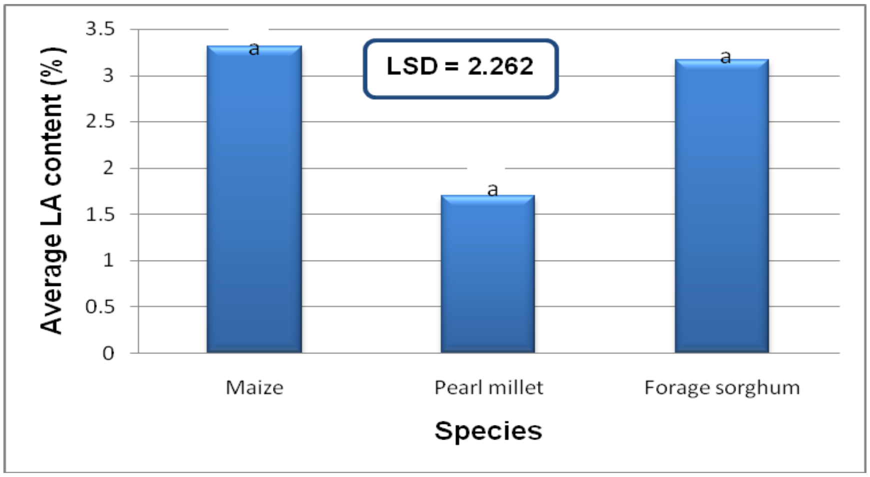

Figure 4.37: The effect of species on LA content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.37, the average LA contents of species varied from 1.70% to 3.31% and did not differ significantly (P≤0.259) from each other when compared results with a Fisher's protected LSD test (LSD = 2.262). Maize and forage sorghum were within the preferable norm of 1.9% to 3.8%.

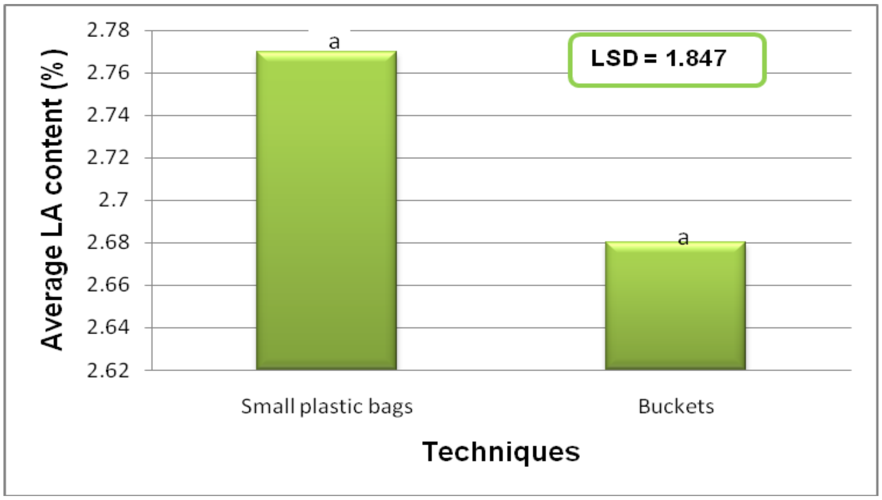

Figure 4.38: The effect of techniques on LA content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.38, the techniques with average LA contents of 2.77% and 2.68%, respectively), differ significantly (P≤0.922) from each other, when compared results with a Fisher's protected LSD test (LSD = 1.847).

4.4.6 pH

The statistical results are shown in Appendix C6. Species (as main treatments), and the interaction between species and techniques, did not influence the pH significantly (P≤0.224 and P≤0.485 respectively). Technique, as main treatment, had significant effects on the pH (P≤0.009). When comparing the results with a Fisher's protected LSD test (LSD = 2.679), significant trends were visible, as indicated in Table 4.20 in different colours.

Table 4.20: The influence of species and ensiling techniques on the pH of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	7.09	5.95	**6.52[a]**
Pearl millet	8.53	6.23	**7.38[a]**
Forage sorghum	7.43	4.16	**5.80[a]**
Average	**7.68[a]**	**5.45[b]**	
LSD: Species =1.895 Techniques = 1.547 Species × Technique = 2.679			

According to results in Table 4.20, pearl millet obtained the highest pH (8.53) when ensiled in small plastic bags (marked red). The pH varied between 5.95 and 7.43 (blue in table) with maize ensiled with both techniques, pearl millet in buckets and forage sorghum in small plastic bags. The lowest pH (4.16) was obtained when forage sorghum was ensiled in buckets.

According to Figure 4.39, the average pH of species varied between 5.80 and 7.38 and differed not significantly (P≤0.224) from each other (LSD = 1.895).

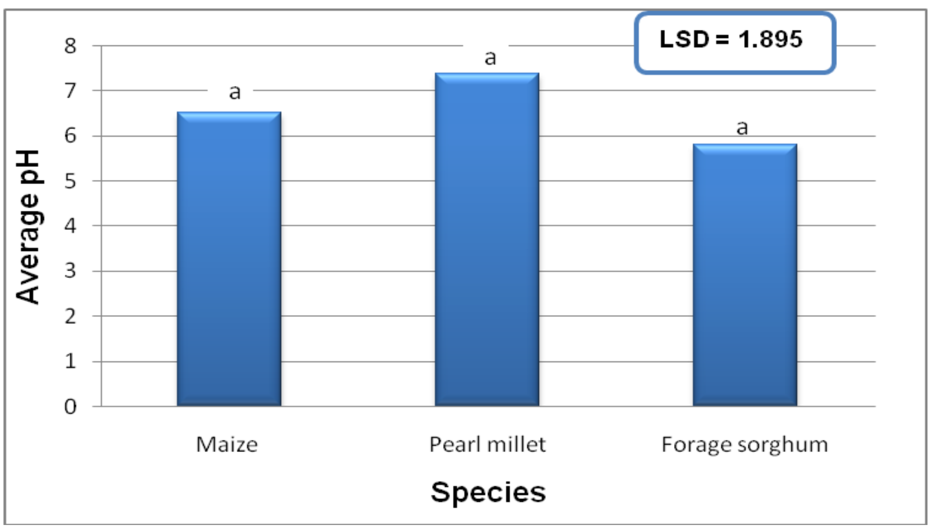

Figure 4.39: The effect of species on pH of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

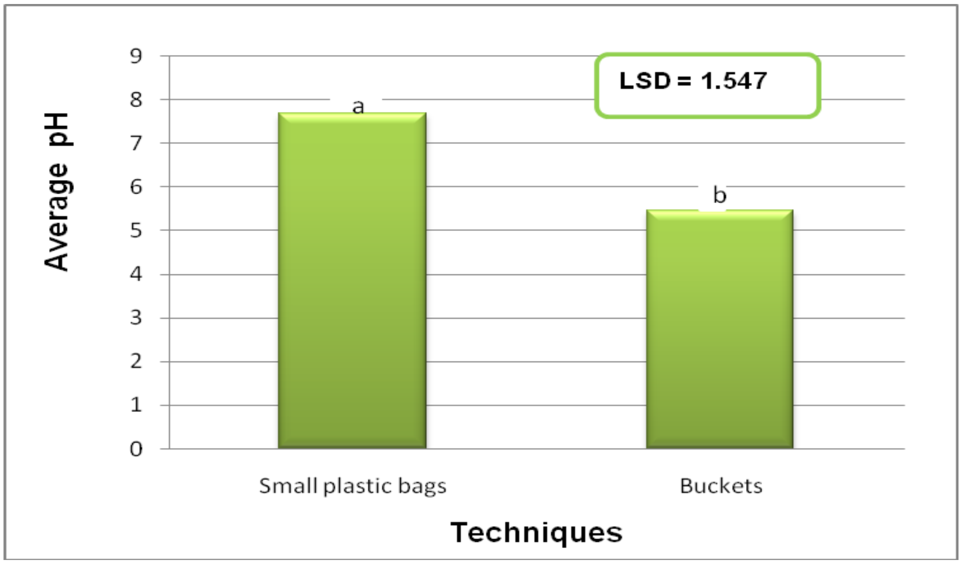

Figure 4.40: The effect of techniques on pH of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.40, the pH of silage in small plastic bags (7.68) was significantly higher (P≤0.009, LSD = 1.547) than that in buckets (5.45).

4.4.7 Crude protein (CP) content

The statistical results are shown in Appendix C7. Both species and techniques, as main treatments, influenced the CP content significantly (P≤0.059 and P≤0.001, respectively). The interaction between the species and techniques did not influence results significantly (P≤0.087). However, when results were compared with a Fisher's protected LSD test (LSD = 2.312), differences were visible, as indicated in Table 4.21 in different colours.

According to results in Table 4.21, the highest CP contents were obtained when maize and pearl millet were ensiled in buckets (13.83% and 14.18%; marked red). The lowest CP contents (9.56% to 11.01%) were obtained when all three species was ensiled in the small plastic bags and forage sorghum silage ensiled in buckets (marked yellow). According to the norms mentioned in Paragraph 4.1.3 the CP content of silage should preferably be not lower than 7% and 9%, thus all species and ensiling techniques resulted in good quality.

Table 4.21: The influence of species and ensiling techniques on the CP content (%) of silage in 2010/11 (Cut 2).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	11.01	14.18	**12.60[a]**
Pearl millet	9.56	13.83	**11.70[ab]**
Forage sorghum	10.24	10.91	**10.57[b]**
Average	**10.27[b]**	**12.97[a]**	
LSD: Species =1.635 Techniques = 1.335 Species × Technique = 2.312			

According to Figure 4.41, the CP content of pearl millet did not differ significantly from that of maize and forage sorghum silage. However the CP content of maize silage differ significantly (P≤0.059) from that forage sorghum silage (LSD = 1.635) with CP contents of 12.60% and 10.57%, respectively).

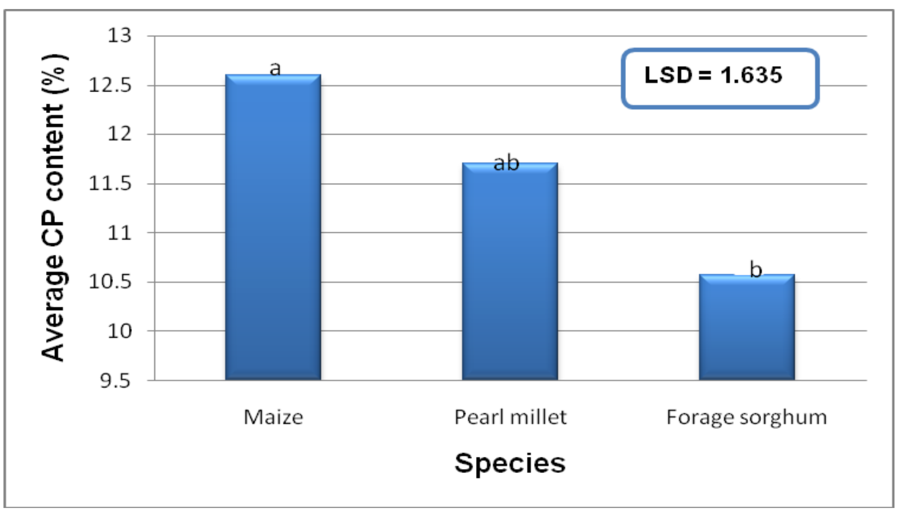

Figure 4.41: The effect of species on CP content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

According to Figure 4.42, the CP content of silage in buckets (12.97%) was highly significantly higher (P≤0.001), than that in small plastic bags silage (10.27%).

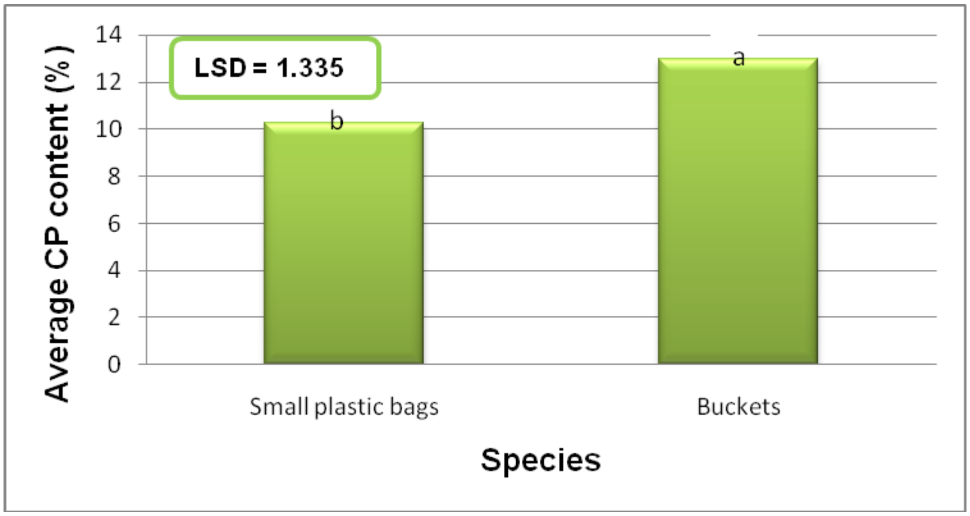

Figure 4.42: The effect of techniques on CP content (%) of silage in 2010/11 (Cut 2).
(a, b, and c indicate significant differences)

4.5 SECOND SEASON RESULTS (2010/2011 GROWING SEASON) FOR CUT 3 (MATURED STAGE)

The nutritional value of the silage was tested by the Cedara Feed Laboratory (Department of Agriculture KZN, Pietermaritzburg) and the data were analysed using the statistical program GenStat® (Payne *et al*. 2009). Results were compared by using the Fisher's protected LSD.

4.5.1 Dry matter (DM) content of silage, after fermentation.

The statistical results are shown in Appendix D1. The DM content of species as main treatment differed significantly (P≤0.001). Techniques (as main treatment) and interaction between species and techniques did not influence the DM content significantly (P≤0.193 and P≤0.325 respectively). When comparing the results, as influenced by the interaction between treatments, with a Fisher's protected LSD test (LSD = 11.34), differences were visible, as indicated in Table 4.22 in different colours.

Table 4.22: The influence of species and ensiling techniques on the DM content (%) of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	65.8	76.4	**71.10[b]**
Pearl millet	92.2	92.7	**92.50[a]**
Forage Sorghum	59.9	61	**60.50[c]**
Average	**72.60[a]**	**76.70[a]**	
LSD: Species = 8.02 Techniques = 6.55 Species × Technique = 11.34			

Three groups were identified, according to Table 4.22, the first group was obtained when pearl millet was ensiled in both techniques (with DM contents of 92.2% and 92.7%, respectively) (marked red). Maize ensiled in both small plastic bags and buckets occurred in the intermediate group (marked blue) with DM contents between 65.8% and 76.4%. The lowest group (marked yellow) consists of DM contents ranging from 59.9% to 61%. According to the results in Table 4.22 ensiling techniques did not influence the DM content significantly (LSD = 6.55). The average DM content of the species differed significantly, pearl millet with an average of 92.5%, maize with 71.1% and forage sorghum with 60.5% (LSD = 8.02)

This high DM content is a result of the matured stage that material was harvested.

According to Figure 4.43, the average DM contents of all species differ significantly ($P \leq 0.001$) from each other. The average DM content of pearl millet was significantly higher than of maize and forage sorghum (LSD = 8.02, $P \leq 0.001$).

According to Figure 4.44, the average DM contents of silage in small plastic bags (72.6%) and buckets (76.7%) did not differ significantly from each other (LSD = 6.55, $P \leq 0.193$).

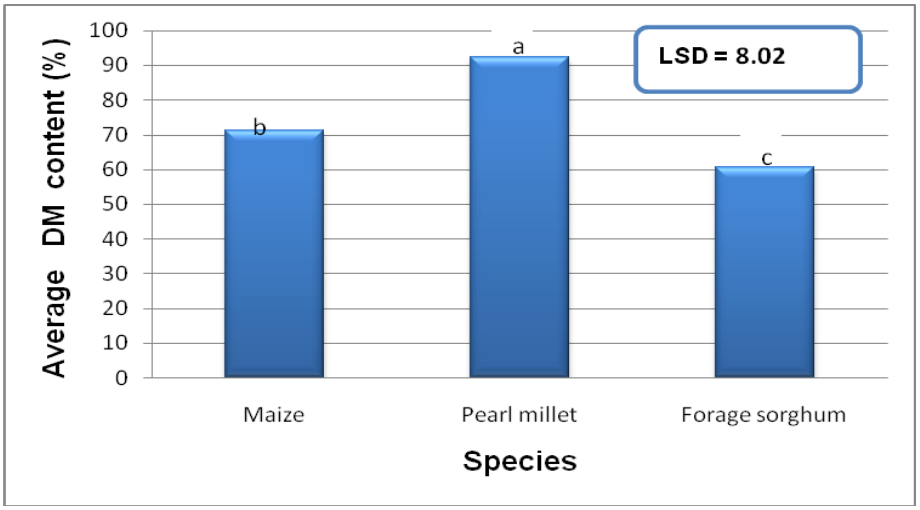

Figure 4.43: The effect of species on Dry matter content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

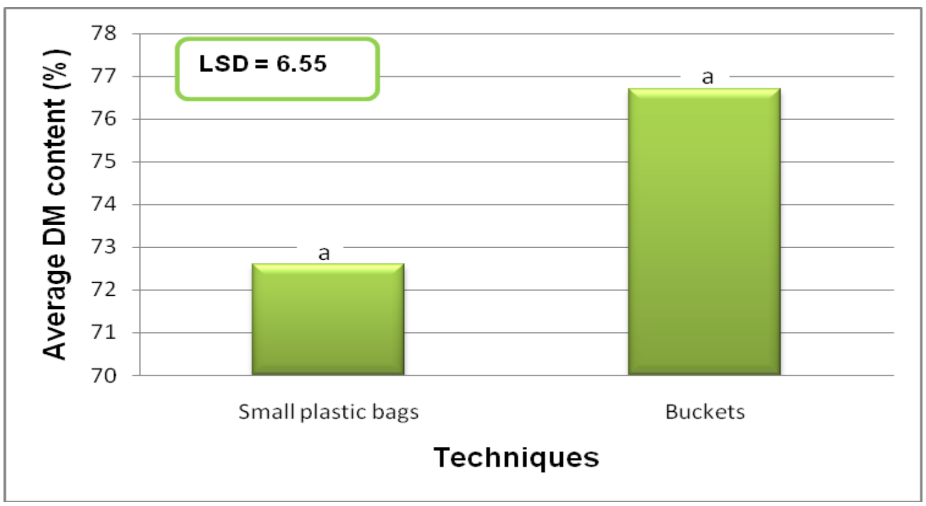

Figure 4.44: The effect of techniques on Dry matter content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

4.5.2 Acid detergent fibre (ADF) content

The statistical results are shown in Appendix D2. Both species and techniques as main treatments had a significant effect on the ADF content ($P \leq 0.001$ and $P \leq 0.018$, respectively). The interaction between the species and techniques did not influence ADF content significantly ($P \leq 0.248$). However, when comparing results with a Fisher's protected LSD of 5.942, differences were visible, as indicated in Table 4.23 in different colours.

According to Table 4.23, maize had the lowest ADF content (34.88%) when ensiled in small plastic bags, (marked yellow). A second group with intermediate ADF contents of 42.67% and 45.9% (marked blue), occurred when maize was ensiled in buckets and pearl millet silage in both techniques. The highest ADF contents (51.53% and 53.22%) was obtained when forage sorghum was ensiled in both techniques, (LSD = 5.942, P≤0.248).

Table 4.23: The influence of species and ensiling techniques on the ADF content (%) of silage in 2010/11 (Cut 3).

Species	**Techniques**		**Average**
	Small plastic bags	**Buckets**	
Maize	34.88	43.05	**38.96^{c}**
Pearl millet	42.67	45.9	**44.28^{b}**
Forage sorghum	51.53	53.22	**58.37^{a}**
Average	**43.03^{b}**	**47.39^{a}**	
LSD: Species = 4.201 Techniques = 3.430 Species × Technique = 5.942			

According to the norms mentioned in Paragraph 4.1.3, the ADF content of silage should preferably be 28% and lower, however ADF contents of up to 35% for silage is also acceptable (Tainton 2000). Maize silage in small plastic bags fell in this category.

Maize and pearl millet, as a main treatments, had the best results (Figure 4.45) in terms of low ADF content (below 48%) and compared well with the norms which indicated that, the ADF content of silage should be below 48%. The average ADF content of forage sorghum (58.37%) differed highly significantly from maize and pearl millet. However, maize and pearl millet differed significantly from each other, (LSD = 4.201, P≤0.001).

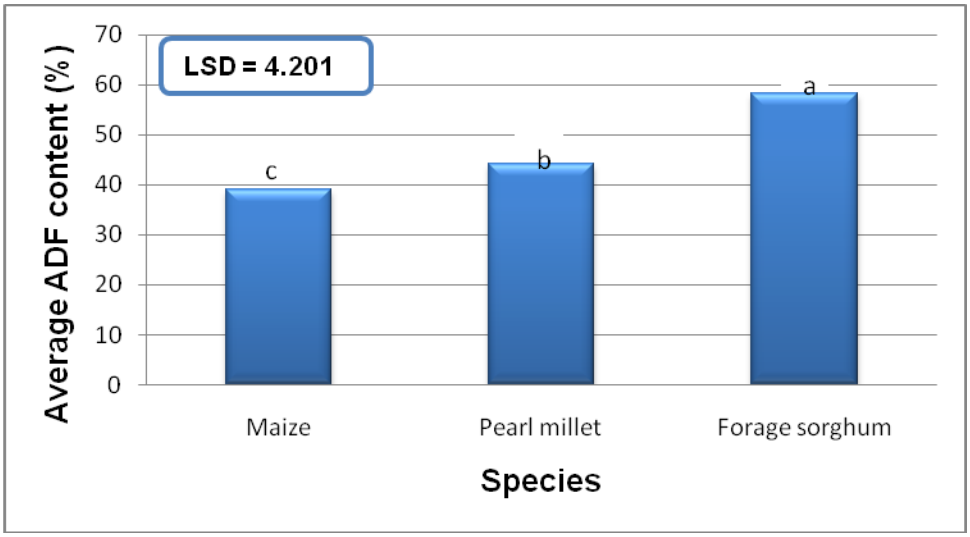

Figure 4.45: The effect of species on ADF content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

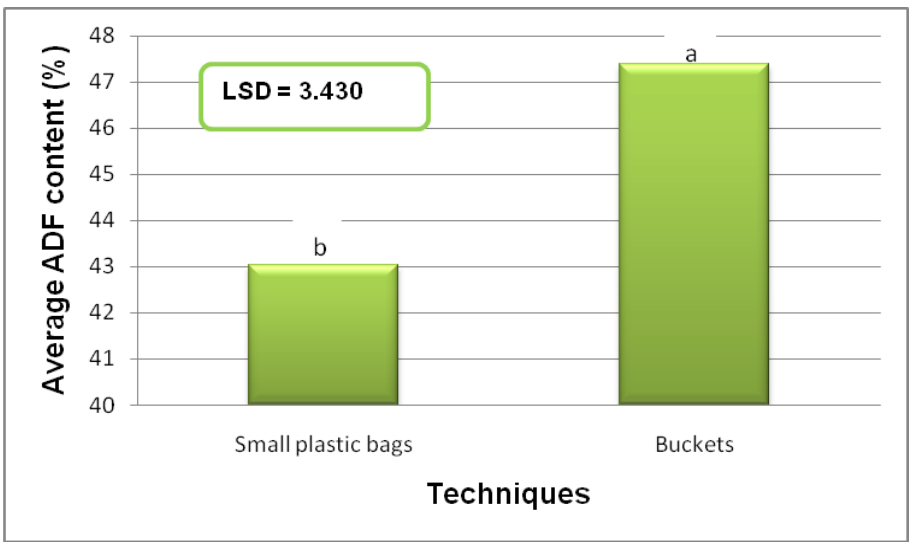

Figure 4.46: The effect of techniques on ADF content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

If techniques of ensiling are considered as a main effect (Figure 4.46), the highest ADF content was obtained in buckets (47.39%) and the lowest small plastic bags (43.03%). They differed significantly from each other (LSD = 3.430, P≤0.018).

4.5.3 Neutral detergent fibre (NDF) content

The statistical results are shown in Appendix D3. The species as main treatment differ significantly on the NDF content (P≤0.002). However, techniques, as main treatment did not differ significantly (P≤0.053). The interaction between the species and techniques did not differ significantly (P≤0.082). However, when compared with a Fisher's protected LSD test (LSD = 8.83), differences were visible, as indicated in Table 4.24 in different colours.

According to results in Table 4.24, the lowest NDF content was obtained when maize was ensiled in small plastic bags (marked yellow) (LSD = 8.53, P≤0.082). The NDF content of the other species ensiled in both techniques and maize ensiled in buckets (68.3% and 77.2%) indicate the highest NDF contents marked red in table.

Table 4.24: The influence of species and ensiling techniques on the NDF content (%) of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	55.9	68.3	**62.1[b]**
Pearl millet	72.7	77.2	**74.9[a]**
Forage sorghum	74.3	72.5	**73.4[a]**
Average	**67.7[a]**	**72.7[a]**	
LSD: Species = 6.24 Techniques = 5.10 Species × Technique = 8.83			

.

According to Figure 4.47, the highest average NDF content was obtained with pearl millet (74.9%) and forage sorghum (73.4%) as main treatment, were significantly higher than maize silage (LSD = 6.24, P≤0.002). These NDF percentages are all above 45%. That is classified as the lowest silage should be.

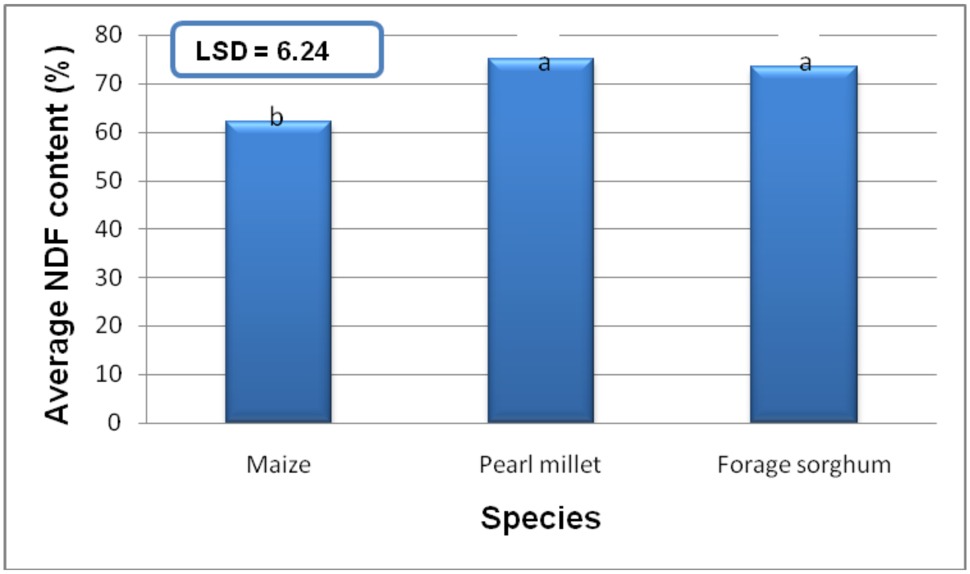

Figure 4.47: The effect of species on NDF content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

According to Figure 4.48, all techniques did not differ significantly from each with the average NDF contents (67.7% and 72.7%, respectively, LSD = 5.1, P≤0.053)

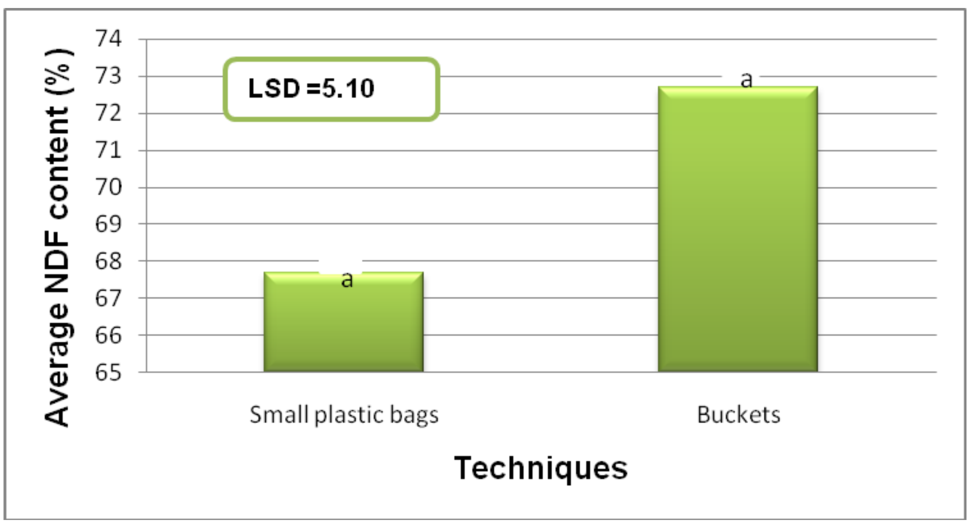

Figure 4.48: The effect of techniques on NDF content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

4.5.4 Ammonia (NH_3) content

The statistical results are shown in Appendix D4. Both species and techniques, as main treatments, influenced the NH_3 content significantly (P≤0.016 and P≤0.001, respectively). The interaction between the species and techniques did not influence results significantly ($P \leq 0.249$). However, when comparing the results with a Fisher's protected LSD of 0.1767; significant trends were visible, as indicated in Table 4.25 in different colours.

Table 4.25: The influence of species and ensiling techniques on the NH_3 content (%) of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	0.427	0.127	**0.277[a]**
Pearl millet	0.240	0.053	**0.147[b]**
Forage sorghum	0.537	0.156	**0.343[a]**
Average	**0.401[a]**	**0.110[b]**	
LSD: Species = 0.1249 Techniques = 0.1020 Species × Technique = 0.1767			

According to Table 4.25, NH_3 content of pearl millet was the lowest (0.053%) when ensiled in buckets (marked yellow). A second group with an intermediate NH_3 content between 0.127% and 0.24% (marked blue), was obtained when pearl millet was ensiled in small plastic bags and maize and forage sorghum silage in buckets. Both these groups are within the norms 0.1% to 0.3%, mentioned in Paragraph 4.1.3. The highest NH_3 content between (0.427% and 0.537%) was obtained when maize and forage sorghum silage were ensiled in small plastic bags, (LSD = 0.1767, $P \leq 0.249$).

According to Figure 4.49, maize and forage sorghum were highly significant different ($P \leq 0.016$) from pearl millet (LSD = 0.1249). However, maize and forage sorghum did not differ significantly. The NH_3 content as influenced by ensiling technique is shown in Figure 4.50.

According to Figure 4.50, the highest average NH_3 content was obtained with small plastic bags (0.401%) and the lower with buckets (0.110%),were significantly different from each other, (LSD = 0.1020, $P \leq 0.001$).

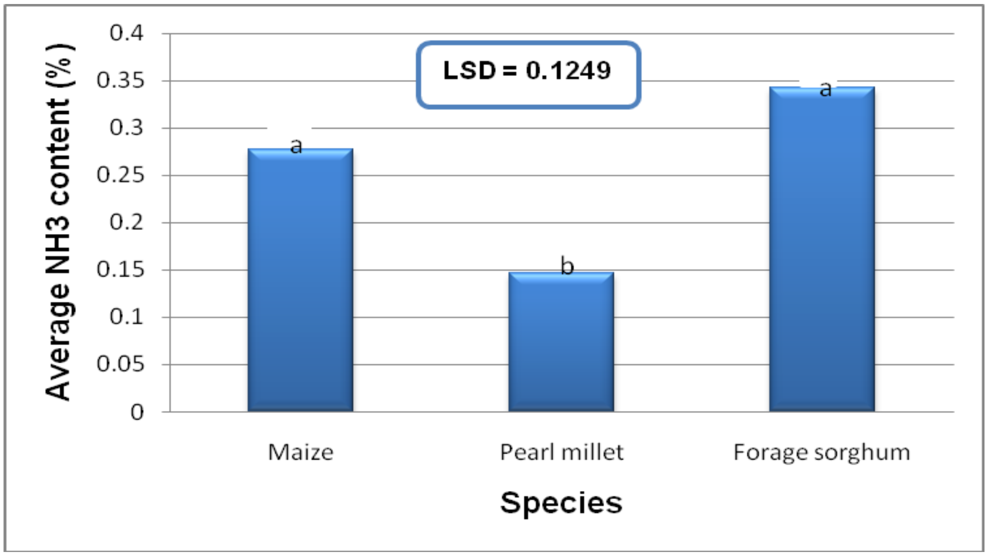

Figure 4.49: The effect of species on NH_3 content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

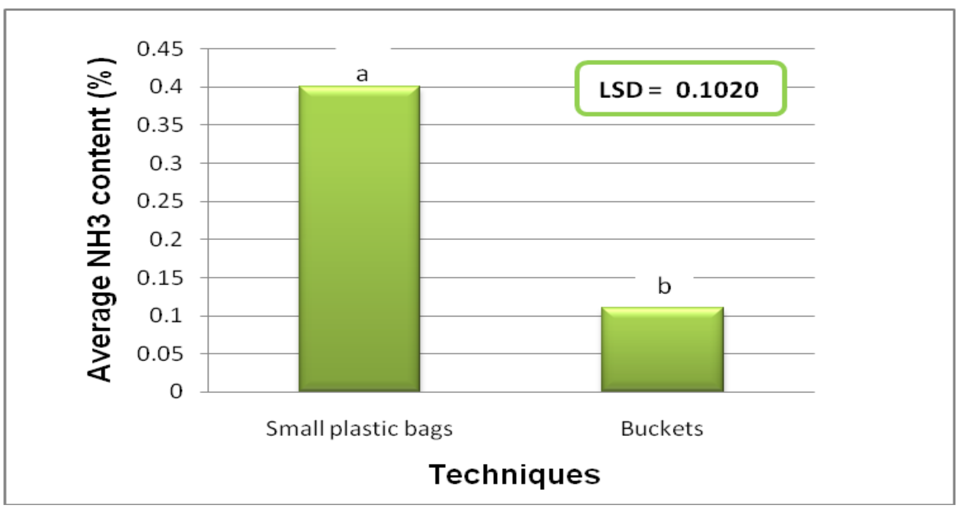

Figure 4.50: The effect of techniques on NH_3 content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

4.5.5 Lactic acid (LA) content

The statistical results are shown in Appendix D5. Species as main treatment influenced the LA content of silage significantly (P≤0.043). Techniques as main treatment and interaction between the species and techniques did not influence the LA content significantly (P≤0.282). However, when compared with a Fisher's protected LSD of 0.3441; significant trends were visible, as shown in Table 4.26 in different colours.

Table 4.26: The influence of species and ensiling techniques on the LA content (%) of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	0.067	0.163	**0.115[b]**
Pearl millet	0.073	0.087	**0.080[b]**
Forage sorghum	0.583	0.169	**0.376[a]**
Average	**0.241[a]**	**0.140[a]**	
LSD: Species = 0.2433 Techniques = 0.1987 Species × Technique = 0.3441			

The preferable lactic acid content should be between 1.9% and 3.8% for silage and none of the treatments were in this category.

According to Table 4.26, the highest LA content (marked red) was obtained when forage sorghum was ensiled in small plastic bags, (LSD = 0.3441, P≤0.087). Other treatments were confined to a second group (marked yellow), with LA contents between (0.067% and 0.169%).

According to Figure 4.51, the highest average LA content was obtained with forage sorghum (0.376%) which differed significantly from that of maize (0.115%) and pearl millet (0.080%). However, maize silage and pearl millet silage did not differ significantly (LSD = 0.2433, P≤0.043).

According to Figure 4.52, techniques of ensiling did not influence the average LA contents (0.241% and 0.140%, respectively), significantly (LSD = 0.1987, P≤0.282).

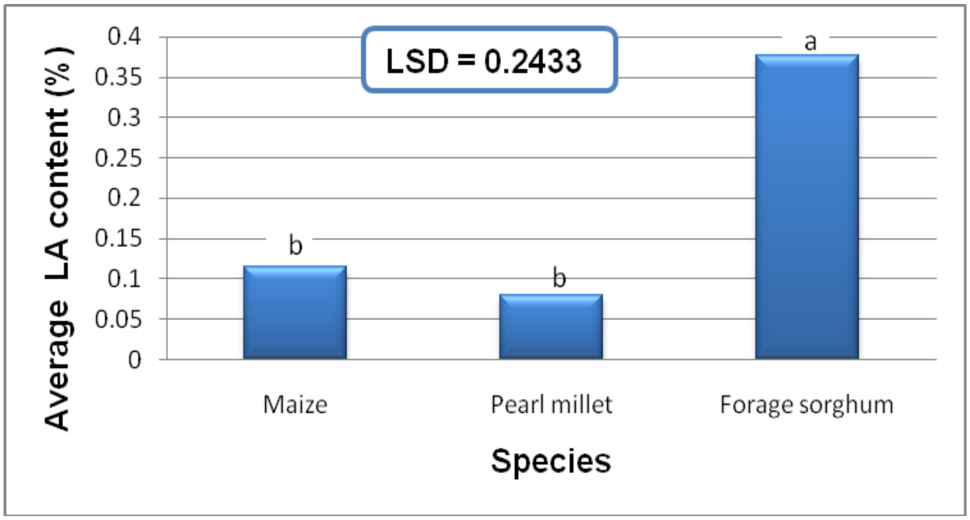

Figure 4.51: The effect of species on LA content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

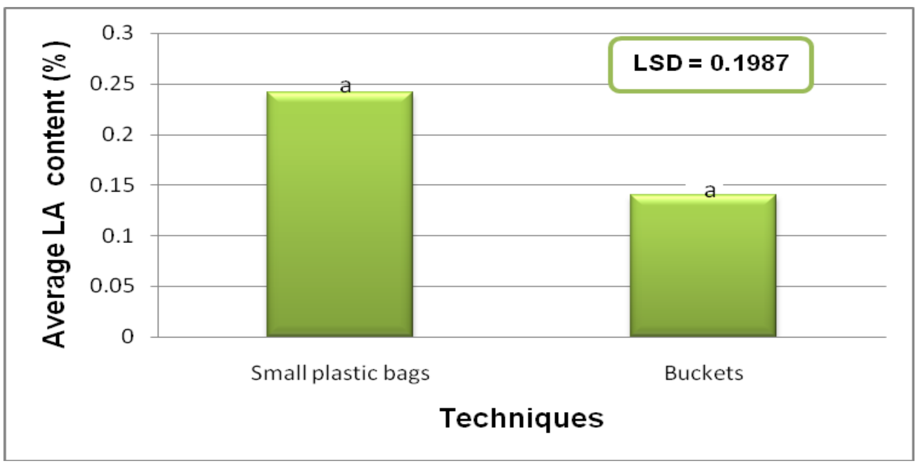

Figure 4.52: The effect of techniques on LA content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

4.5.6 pH

The statistical results are shown in Appendix D6. The pH of species as main treatment differ significantly ($P \leq 0.001$). However, techniques, as main treatment ($P \leq 0.029$) and interaction between species and techniques did not influence pH significantly ($P \leq 0.002$), as indicated in Table 4.27 in different colours.

Table 4.27: The influence of species and ensiling techniques on the pH of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	8.67	7.20	**7.93[b]**
Pearl millet	5.96	6.26	**6.11[c]**
Forage sorghum	8.54	8.54	**8.54[a]**
Average	**7.73[a]**	**7.33[a]**	
LSD: Species = 0.4220 Techniques = 0.3445 Species × Technique = 0.5968			

According to Table 4.27, the highest pH (between 8.537 and 8.67) were obtained when maize was ensiled in small plastic bags and forage sorghum ensiled in both techniques (marked red). A second group with an intermediate pH of 7.2 (marked blue), was obtained when maize was ensiled in buckets. The lowest pH, between 5.963 and 6.257, was obtained when pearl millet was ensiled in both small plastic bags and buckets (LSD = 0.5968, P≤0.002).

The ideal pH for good silage should be below 5 (4.3 - 4.5 is ideal for maize and forage sorghum silage) and none of the result in Table 4.27 were in this category.

According to Figure 4.53, the highest average pH was obtained with forage sorghum (8.540), which differ significantly from maize (7.93) and pearl millet (6.11) (LSD = 0.422, P≤0.001). Maize and pearl millet differed significantly from each other.

According to Figure 4.54, pH (average) as influenced by ensiling techniques (7.726 and 7.331, respectively), did not differ significantly (P≤0.029) from each other (LSD =0.3445).

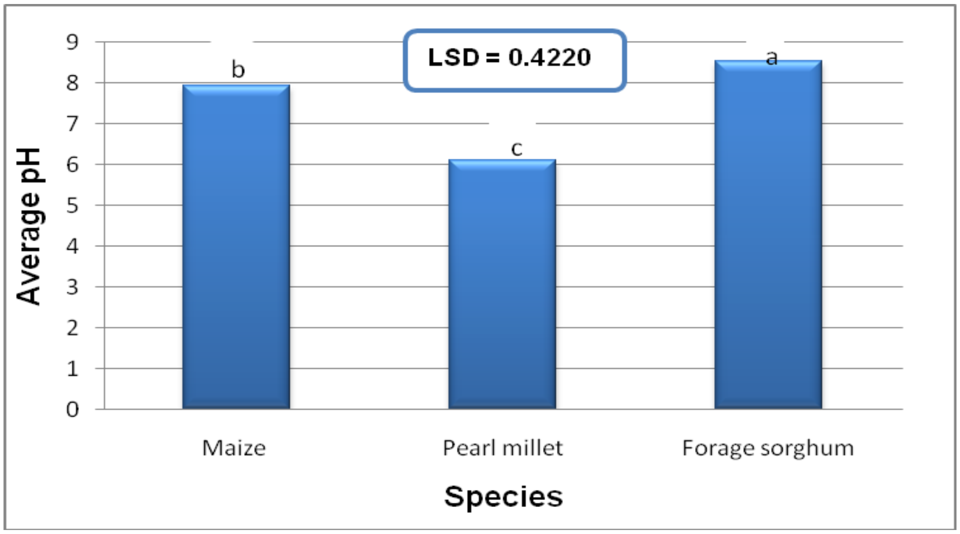

Figure 4.53: The effect of species on pH of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

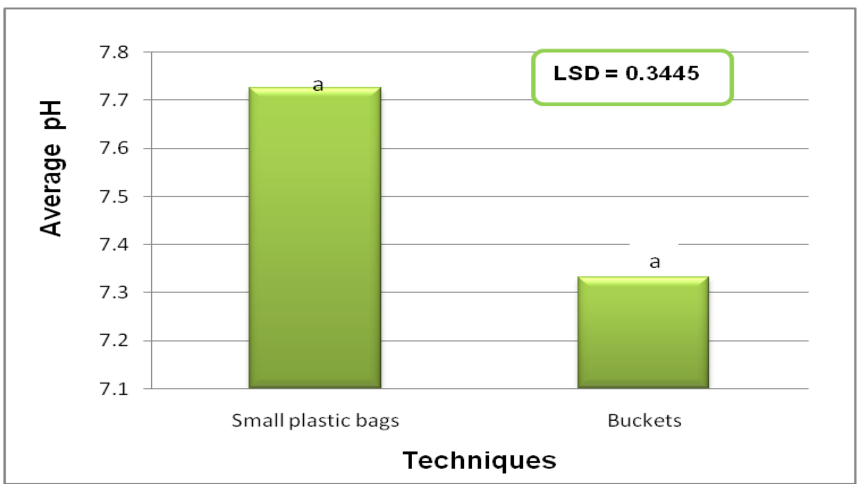

Figure 4.54: The effect of techniques on pH of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

4.5.7 Crude protein (CP) content

The statistical results are shown in Appendix D7. The CP content of species (as main treatment) differ significantly ($P \leq 0.008$), while techniques, as main treatment did not influence CP content significantly ($P \leq 0.461$). The interaction between species and techniques did not influence pH significantly ($P \leq 0.801$). However, when compared with a Fisher's protected LSD of 4.014, significant trends were visible, as indicated in Table 4.28 in different colours.

Table 4.28: The influence of species and ensiling techniques on the CP content (%) of silage in 2010/11 (Cut 3).

Species	Techniques		Average
	Small plastic bags	Buckets	
Maize	13.88	12.32	**13.10b**
Pearl millet	14.84	13.89	**14.36[a]**
Forage sorghum	9.31	9.44	**9.38[c]**
Average	**12.68[a]**	**11.88[a]**	
LSD:	Species = 2.838		
	Techniques = 2.317		
	Species × Technique = 4.014		

According to Table 4.28, the highest CP contents (13.88% and 14.84%) were obtained when maize was ensiled in small plastic bags and pearl millet in both techniques (marked red). A second group with intermediate CP content of 12.32% (marked blue), was obtained when maize silage was ensiled in buckets. The lowest CP contents (marked yellow) (9.31% and 9.44%) was obtained when forage sorghum was ensiled with both techniques (LSD = 4.014, P≤0.801).

According to the norms mentioned in Paragraph 4.1.3 the CP content of silage should preferably be not lower than 7% and 9% and all the results in Table 4.28 are higher than these norms. That means that the silage can maintain animal's weights and even will result in weight gain (>12% CP)

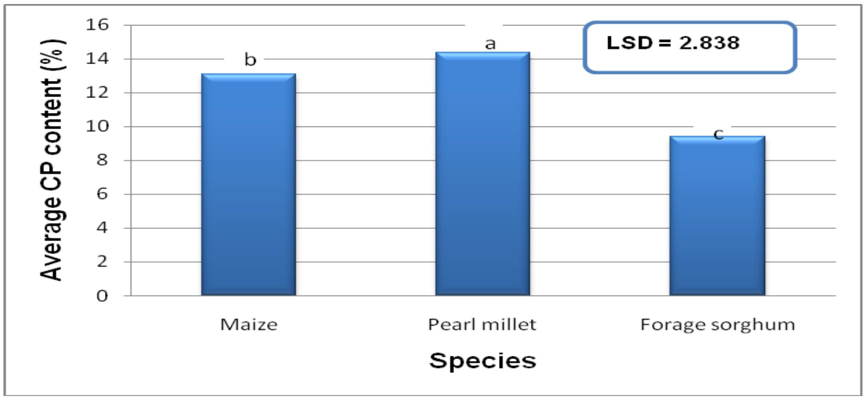

Figure 4.55: The effect of species on CP content (%) of silage in 2010/11 (Cut 3).
(a, b, and c indicate significant differences)

According to Figure 4.55, the highest average CP contents was obtained with pearl millet (14.36%), which differed significantly from that of maize and forage sorghum (LSD = 2.838, P≤0.008). The CP content of maize and forage sorghum also differed significantly.

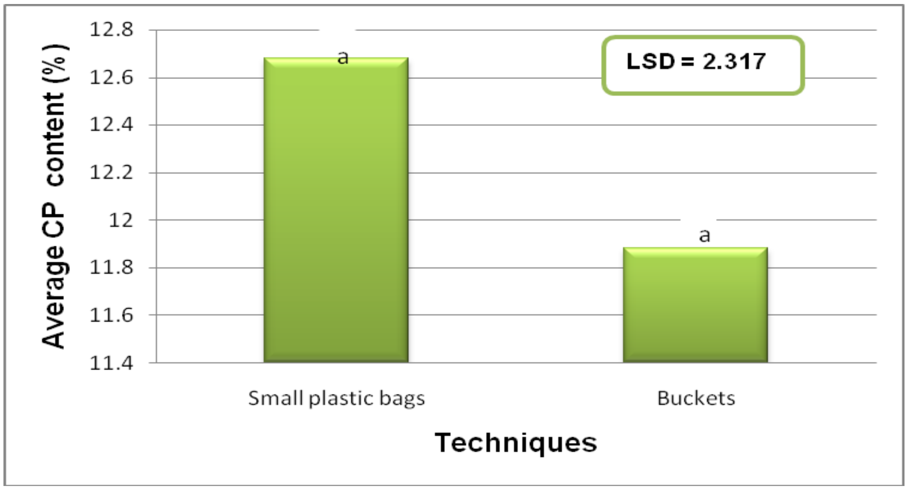

Figure 4.56: The effect of techniques on CP content (%) of silage in 2010/11 (Cut 3)

(a, b, and c indicate significant differences)

According to Figure 4.56, all techniques did not influence the average CP content (12.68% and 11.88%, respectively; LSD = 2.317, P≤0.461).

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

5.1.1 First season 2009/2010

The ideal DM content for planting material to be ensiled should be between 35% and 38% and not lower than 30%. In this study the species with lowest DM content was pearl millet and forage sorghum (22.29% and 24.29% respectively). The average DM content of silage made in black plastic bags was 23.27%, while it was above 28% in the case of other two ensiling techniques. These results indicated that the DM content was too low before ensiling

The ADF content of maize ensiled in small plastic bags and buckets was on average lower than 35.5%. The ADF for maize in black plastic bags and forage sorghum in small plastic bags was below 45%. For the rest of the species and ensiling techniques it was above 46%. The average ADF content of silage made in black plastic bags was 48.3%, while it was lower than 45% in the case of study of the two ensiling techniques.

According to Wilkinson (2005) the ideal NDF content of fodder should be between 45% and 55%. In this study the NDF content of silage of all four crop species were higher than 60% with maize at 62.75% and other three species above 70%. The highest NDF content (73.8%) was obtained in the black plastic bags, while it was lower than 70% in the other two ensiling techniques or containers.

Wilkinson (2005) indicated that the ammonia content should vary between 0.05% and 0.35%. The highest ammonia content measured in this study was 0.035%, which was low and in the mentioned limits.

Among the acids that are produced in silage lactic acid is the most important, it helps to produced natural micro-organisms in the plant material during silage fermentation

(Wilkinson, 2005). In the present study lactic acid produced by all crops and techniques range from 0.00% to 0.060% and that is lower than the ideal content of 1.9% to 3.8%. According to Mac Pherson and Violante (1966) low pH of silage is often associated with poor intakes. According to norms in Chapter 4 it should not be lower than 4.3. In this study the pH ranged between 5.4 and 8.7, with maize in small plastic bags and buckets silage with the lowest (4.28 and 4.12 respectively).

The ideal crude protein (Orosz, 2010) should not be lower than 7% to 9%. The result in this study indicated that *Panicum maximum* produced less than 7% CP (5.86% to 8.27%). The CP content of the other three species was higher than 10.5%, with maize and pearl millet the highest (> 14.9%).

5.1.2 Second session (2010/2011)

During this part of the study, the silage was made at different crop maturity stages.

Soft dough stage (Cut 1)

The ideal DM content for planting material to be ensiled should be between 35% and 38% and not lower than 30%. In this study the treatments that were close to these norms were pearl millet in small plastic bags (27.1%) and *P. maximum*, with 32.8% in small plastic bags and 28.6% in buckets. The DM content of the rest of the treatments varied between 14.9% and 20.9%.

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The ADF content of maize was on average the lowest (48.3%) when ensiled 9 small plastic bags. The ADF content of pearl millet and forage sorghum was 42.4% and 46.7% respectively in small plastic bags, while it was above 49.0 % for the rest of the treatments.

In this cutting stage the NDF content of silage in all treatments was higher than 65.8% that was above the ideal NDF content of 45% and 55%. The highest average NDF content (74.1%) was obtained in the buckets, while in the small plastic bags was below 69.9%.

Wilkinson (2005) indicated the ideal ammonia content should vary between 0.05% and 0.3%. Only *P. maximum* in buckets (0.29%) was within these norms all other crops and techniques obtained an ammonia content that ranged from 0.695% to 1.24%, which is above the ideal content.

In this cutting stage the lactic acid content of forage sorghum was 4.89%% and for maize 1'89%, both in small plastic bags. For the rest of the treatments it ranged from 0.14% to 1.21% that is lower than the ideal content of 1.9% to 3.8%.

The pH of most treatments was above 7.5. It was 5.4 for *P. maximum*, in buckets, and 5.8 for forage sorghum, in small plastic bags, which was closer to the norm of 4.3.

The ideal crude protein (Orosz, 2010) should not be lower than 7% to 9%. The result in this cutting stage indicated that in case of *Panicum maximum* was lower than 9%. The CP content of the other treatments varied between 10.53% and 15.07%.

Hard dough stage (Cut 2)

The ideal DM content for planting material to be ensiled should be between 35% and 38% and not lower than 30%. In this cutting stage the DM content of most treatments was between 30.5% and 48.4%. It was only for pearl millet and forage sorghum, both in small plastic bags lower than 30%

The ADF content of maize (both ensiling techniques) and forage sorghum in buckets was lower than 40%, while it was 42.1% for forage sorghum, in small plastic bags, and 46.2% for pearl millet, in buckets. Producing silage in buckets resulted on average the lowest ADF content 40.5%.

According to Wilkinson (2005) the ideal NDF content of fodder should be between 45% and 55%. In this cutting stage the NDF content of silage of all three crop species and techniques were higher than 55%.

Wilkinson (2005) indicated the ideal ammonia content should vary between 0.05% and 0.3%. The highest ammonia content obtained in this stage was 0.0.747% for pearl millet, in small plastic bags, and the lowest was 0.147% (forage sorghum in buckets). For the rest of the treatments, it varied between 0.38% and 0.617%, which was above the limit mentioned by Wilkinson (2005).

In this cutting stage pearl millet, in plastic bags, produced only 0.84% lactic acid. The rest of the treatments produced between 2.51% and 4.11%, which is within the ideal range of 1.9% to 3.8% lactic acid.

According to norms in Chapter 4 the pH should not be lower than 4.3. In this cutting stage the pH of all crops and techniques ranged between 5.95 and 8.53, accept forage sorghum, in buckets, with a pH of 4.16.

The ideal crude protein (Orosz, 2010) should not be lower than 7% to 9%. The CP content in this cutting stage ranged between 9.56% and 14.16%

Matured stage (Cut 3)

The ideal DM content for planting material to be ensiled should be between 35% and 38% and not lower than 30%. In this matured cutting stage the DM content ranged between 59.9% and 92.5% which is an indication that the DM content was too high before ensiling.

The ADF content of maize, in small plastic bags, was the lowest (34.88%), while it varied for maize (in buckets) and pearl millet (small bags and buckets) between 43.05% and 45.9%. The ADF content of forage sorghum was on average 58.37%.

According to Wilkinson (2005) the ideal NDF content of fodder should be between 45% and 55%. In this cutting stage the NDF content of maize in small plastic bags was 55.9%. For the rest the NDF content of silage varied between 68.3% and 77.2%.

Wilkinson (2005) shows the acceptance ammonia content should vary between 0.05% and 0.3%. The highest ammonia content obtained in this stage was 0.427% and 0.537%, for maize and forage sorghum (both in small plastic bags). The ammonia content for the rest of the treatments varied between 0.127% and 0.24%, which were within the limits mentioned by Wilkinson (2005).

According to norms in Chapter 4 the LA content of silage should be between 1.9% and 3.8%. In this late cutting stage the LA content varied between 0.067% and 0.583%

According to norms in Chapter 4 the pH should not be lower than 4.3. In this stage the pH ranged between 5.96 and 8.67, which might influence intake by animals negatively.

The ideal crude protein (Orosz, 2010) should not be lower than 7% to 9%. In this late cutting stage the CP content ranged from 9.31% to 14.84%, with lowest in forage sorghum.

5.2 CONCLUSION

If all quality norms is taken in consideration maize can still be classified as a good silage crop. Silage of similar quality can be produced from forage sorghum and pearl millet. Pearl millet produced relative good quality silage when ensiled in a mature stage.

Ensiling in small plastic bags and buckets resulted in good quality silage. There was a trend that buckets resulted in better quality silage when harvested in the hard dough stage. Black refuge plastic bags are not suggested for silage making.

Comments on specific quality norms:

1. A precise cutting stage to obtain an acceptable DM content should still be researched and defined.
2. Acceptable ADF and NDF percentages were possible to obtain with maize, but problems were experienced with forage sorghum and pearl millet.

3. To produce silage with acceptable NH_3 and lactic acid contents and pH seemed to be more problematic as in commercial silage making.
4. The CP content of all treatment were according to norms set for good animal production

5.3 RECOMMENDATION

It is recommended that farmers use species such as *Panicum maximum*, maize, pearl millet and forage sorghum for making silage in small quantities. According to the findings of this study, the most effective ensilage techniques which can be used are small bags silage and plastic bags. Black plastic bags should be avoided. The crop species should be harvested in the soft dough stage, since the quality of silage is severely affected when older material is used..

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Appendix A1

First season 2009/10 Silage analysis **Dry matter content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: DM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	11.043	11.043	1.25	
Rep.*Units* stratum					
Species	3	341.432	113.811	12.88	<.001
Technique	2	150.089	75.044	8.49	0.006
Species.Technique	6	149.743	24.957	2.82	0.065
Residual	11	97.233	8.839		
Total	23	749.539			

Tables of means

Variate: DM

Grand mean 26.78

Species	1	2	3	4
	28.53	32.02	22.29	24.29

Technique	1	2	3
	28.21	23.27	28.87

Species	Technique	1	2	3
1		25.90	27.04	32.64
2		36.84	23.57	35.66
3		24.42	19.62	22.81
4		25.68	22.83	24.37

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	1.214	1.051	2.102

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11

l.s.d.	3.778	3.272	6.5

Stratum standard errors and coefficients of variation

Variate: DM

Stratum	d.f.	s.e.	cv%
Rep	1	0.959	3.6
Rep.*Units*	11	2.973	11.1

===== Comparing differences between Species means =====

Fisher's protected least significant difference test

Species

	Mean
2	32.02 a
1	28.53 a
4	24.29 b
3	22.29 b

==== Comparing differences between Technique means ====

Fisher's protected least significant difference test

Technique

	Mean
3	28.87 a
1	28.21 a
2	23.27 b

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	25.90	7.566
2	2	36.84	1.068
3	2	24.42	0.339
4	2	25.68	2.114

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	27.04	2.348
2	2	23.56	2.468
3	2	19.62	0.276
4	2	22.83	5.388

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	32.64	1.301
2	2	35.66	1.442
3	2	22.81	0.170
4	2	24.37	0.891

Appendix A2

First season 2009/10 Silage analysis **Acid detergent fiber content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: ADF

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	6.19	6.19	0.45	
Rep.*Units* stratum					
Species	3	912.74	304.25	22.32	<.001
Technique	2	89.21	44.61	3.27	0.077
Species.Technique	6	82.10	13.68	1.00	0.469
Residual	11	149.95	13.63		
Total	23	1240.20			

Tables of means

Variate: ADF

Grand mean 45.66

Species	1	2	3	4
	52.42	35.66	48.04	46.52

Technique	1	2	3
	43.76	48.30	44.92

Species	Technique	1	2	3
1		54.12	52.75	50.39
2		31.82	40.31	34.86
3		46.82	49.07	48.24
4		42.29	51.09	46.19

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	1.507	1.305	2.611

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
l.s.d.	4.692	4.063	8.126

Stratum standard errors and coefficients of variation

Variate: ADF

Stratum	d.f.	s.e.	cv%
Rep	1	0.718	1.6
Rep.*Units*	11	3.692	8.1

===== Comparing differences between Species means =====

Fisher's protected least significant difference test

Species

	Mean
1	52.42 a
3	48.04 ab
4	46.52 b
2	35.66 c

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	54.12	0.665
2	2	31.82	2.524
3	2	46.82	1.174
4	2	42.28	3.274

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	52.76	0.120
2	2	40.31	7.863
3	2	49.06	6.923
4	2	51.09	3.762

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	50.39	0.742
2	2	34.86	1.768
3	2	48.24	2.065
4	2	46.19	2.319

Appendix A3

First season 2009/10 Silage analysis **Neutral detergent fiber content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: NDF

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	29.15	29.15	2.01	
Rep.*Units* stratum					
Species	3	727.64	242.55	16.75	<.001
Technique	2	94.48	47.24	3.26	0.077
Species.Technique	6	143.61	23.94	1.65	0.222
Residual	11	159.32	14.48		
Total	23	1154.21			

Tables of means

Variate: NDF

Grand mean 71.00

Species	1	2	3	4
	77.94	62.75	73.11	70.22

Technique	1	2	3
	69.47	73.81	69.74

Species	Technique	1	2	3
1		79.82	76.32	77.68
2		60.19	69.01	59.05
3		71.36	74.07	73.90
4		66.51	75.81	68.33

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	1.554	1.346	2.691

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
l.s.d.	4.836	4.188	8.376

Stratum standard errors and coefficients of variation

Variate: NDF

Stratum	d.f.	s.e.	cv%
Rep	1	1.559	2.2
Rep.*Units*	11	3.806	5.4

===== Comparing differences between Species means =====

Fisher's protected least significant difference test

Species

	Mean
1	77.94 a
3	73.11 ab
4	70.22 b
2	62.75 c

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	79.82	0.141
2	2	60.20	5.381
3	2	71.36	1.004
4	2	66.50	5.636

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	76.32	0.594
2	2	69.02	5.706
3	2	74.08	9.242
4	2	75.81	0.983

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	77.68	0.212
2	2	59.05	1.450
3	2	73.90	1.881
4	2	68.33	1.322

Appendix A4

First season 2009/10 Silage analysis **Ammonia content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: NH3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	0.00006667	0.00006667	1.16	
Rep.*Units* stratum					
Species	3	0.00215000	0.00071667	12.45	<.001
Technique	2	0.00000833	0.00000417	0.07	0.931
Species.Technique	6	0.00052500	0.00008750	1.52	0.259
Residual	11	0.00063333	0.00005758		
Total	23	0.00338333			

Tables of means

Variate: NH3

Grand mean 0.0158

Species	1	2	3	4
	0.0067	0.0283	0.0217	0.0067

Technique	1	2	3
	0.0163	0.0150	0.0163

Species	Technique	1	2	3
1		0.0100	0.0000	0.0100
2		0.0350	0.0250	0.0250
3		0.0200	0.0200	0.0250
4		0.0000	0.0150	0.0050

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	0.00310	0.00268	0.00537

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11

l.s.d.	0.00964	0.00835	0.01670

Stratum standard errors and coefficients of variation

Variate: NH3

Stratum	d.f.	s.e.	cv%
Rep	1	0.00236	14.9
Rep.*Units*	11	0.00759	47.9

===== Comparing differences between Species means =====

Fisher's protected least significant difference test

Species

	Mean
2	0.02833 a
3	0.02167 a
1	0.00667 b
4	0.00667 b

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	0.01000	0.000000
2	2	0.03500	0.007071
3	2	0.02000	0.014142
4	2	0.00000	0.000000

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	0.00000	0.000000
2	2	0.02500	0.007071
3	2	0.02000	0.014142
4	2	0.01500	0.007071

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	0.01000	0.000000
2	2	0.02500	0.007071
3	2	0.02500	0.007071
4	2	0.00500	0.007071

Appendix A5

First season 2009/10 Silage analysis **Lactic acid content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: Lactic Acid

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	0.003267	0.003267	0.84	
Rep.*Units* stratum					
Species	3	0.013233	0.004411	1.14	0.376
Technique	2	0.005700	0.002850	0.74	0.501
Species.Technique	6	0.021967	0.003661	0.94	0.502
Residual	11	0.042633	0.003876		
Total	23	0.086800			

Tables of means

Variate: Lactic Acid

Grand mean 0.020

Species	1	2	3	4
	0.005	0.060	0.013	0.002

Technique	1	2	3
	0.022	0.000	0.037

Species	Technique	1	2	3
1		0.015	0.000	0.000
2		0.030	0.000	0.150
3		0.040	0.000	0.000
4		0.005	0.000	0.000

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	0.0254	0.0220	0.0440

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
l.s.d.	0.0791	0.0685	0.1370

Stratum standard errors and coefficients of variation

Variate: Lactic Acid

Stratum	d.f.	s.e.	cv%
Rep	1	0.0165	82.5
Rep.*Units*	11	0.0623	311.3

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	0.01500	0.02121
2	2	0.03000	0.01414
3	2	0.04000	0.01414
4	2	0.00500	0.00707

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	0.00000	0.00000
2	2	0.00000	0.00000
3	2	0.00000	0.00000
4	2	0.00000	0.00000

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	0.00000	0.00000
2	2	0.15000	0.21213
3	2	0.00000	0.00000
4	2	0.00000	0.00000

Appendix A6

First season 2009/10 Silage analysis **pH content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	1.696	1.696	1.15	
Rep.*Units* stratum					
Species	3	14.432	4.811	3.27	0.063
Technique	2	12.201	6.100	4.14	0.046
Species.Technique	6	17.049	2.842	1.93	0.163
Residual	11	16.206	1.473		
Total	23	61.584			

Tables of means

Variate: pH

Grand mean 6.67

Species	1	2	3	4
	7.82	5.64	6.52	6.72

Technique	1	2	3
	6.27	7.68	6.08

Species	Technique	1	2	3
1		7.88	8.45	7.12
2		4.28	8.52	4.12
3		5.86	7.32	6.38
4		7.05	6.42	6.69

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	0.496	0.429	0.858

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
l.s.d.	1.542	1.336	2.671

Stratum standard errors and coefficients of variation

Variate: pH

Stratum	d.f.	s.e.	cv%
Rep	1	0.376	5.6
Rep.*Units*	11	1.214	18.2

==== Comparing differences between Technique means ====

Fisher's protected least significant difference test

Technique

	Mean
2	7.678 a
1	6.268 b
3	6.080 b

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	7.885	0.6435
2	2	4.280	0.3111
3	2	5.855	0.8697
4	2	7.050	1.7112

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	8.450	0.1131
2	2	8.520	0.6223
3	2	7.320	2.7153
4	2	6.420	2.1496

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	7.125	0.2333
2	2	4.125	0.0071
3	2	6.380	0.7495
4	2	6.690	0.8344

Appendix A7

First season 2009/10 Silage analysis **Crude protein content** of *P. maximum* (harvested on 04/03/10) and maize, pearl millet & forage sorghum(harvested on 17/03/10) using small plastic bags, black plastic bags and bucket s as silage techniques.

Analysis of variance

Variate: Crude Protein

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	2.898	2.898	2.83	
Rep.*Units* stratum					
Species	3	141.544	47.181	46.03	<.001
Technique	2	7.307	3.653	3.56	0.064
Species.Technique	6	7.078	1.180	1.15	0.396
Residual	11	11.275	1.025		
Total	23	170.101			

Tables of means

Variate: Crude Protein

Grand mean 9.72

Species	1	2	3	4
	5.70	12.21	10.30	10.67

Technique	1	2	3
	9.39	10.50	9.27

Species	Technique	1	2	3
1		5.35	6.68	5.06
2		11.72	13.02	11.88
3		10.35	9.93	10.63
4		10.12	12.35	9.53

Standard errors of means

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
e.s.e.	0.413	0.358	0.716

Least significant differences of means (5% level)

Table	Species	Technique	Species Technique
rep.	6	8	2
d.f.	11	11	11
l.s.d.	1.287	1.114	2.228

Stratum standard errors and coefficients of variation

Variate: CrudeProtein

Stratum	d.f.	s.e.	cv%
Rep	1	0.491	5.1
Rep.*Units*	11	1.012	10.4

===== Comparing differences between Species means =====

Fisher's protected least significant difference test

Species

	Mean
2	12.208 a
4	10.667 b
3	10.305 b
1	5.700 c

========== Summary of original data =========

Technique	1		
	Nobservd	Mean	s.d.
Species			
1	2	5.355	0.2899
2	2	11.725	1.5768
3	2	10.350	1.7819
4	2	10.125	0.1485

Technique	2		
	Nobservd	Mean	s.d.
Species			
1	2	6.685	1.1243
2	2	13.025	1.2799
3	2	9.930	1.4001
4	2	12.350	1.0182

Technique	3		
	Nobservd	Mean	s.d.
Species			
1	2	5.060	0.8910
2	2	11.875	0.4879
3	2	10.635	0.9263
4	2	9.525	0.7849